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9 FINAL TECHNICAL REPORT.

6 INVESTIGATION INTO ADAPTIVE CONTROL
OF A SLIP-CAST, REACTION-BONDED
SILICON-NITRIDE PROCESS VIA
ADAPTIVE LEARNING NETWORK MODELING.

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12 97

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FOREWORD

This Final Technical Report presents the results obtained under Contract MDA903-79-C-0186, DARPA Order Number 3700-9Y10-62712E. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either express or implied, of the Defense Advanced Research Projects Agency or the United States Government.

This contract with the Defense Supply Service - Washington was initiated by the Defense Advanced Research Projects Agency and was under the technical direction of Dr. Michael J. Buckley, Program Manager, Material Sciences Office, DARPA, and Dr. Henry Graham, Air Force Materials Laboratory/LLM.

The Program Manager for Adaptronics was Dr. Anthony N. Mucciardi, the Principal Investigator was Mr. Dixon Cleveland, and major contributors to the work were Messrs. Peter M. Garafola and Basil A. Decina.

The reaction-bonded silicon nitride process data used in this work was obtained by and provided to Adaptronics by the AiResearch Manufacturing Company and AiResearch Casting Company which are Divisions of the Garrett Corporation. Garrett obtained the data from experimental work performed under Phase 2 of an Air Force Materials Laboratory project [1] to demonstrate capability of increased yield of slip-cast ceramic vanes as components for high-performance turbine engines. Mr. David W. Richerson of AMC and Michael E. Rorabaugh of ACC were primarily responsible for the data collection and compilation.

ABSTRACT

A program was conducted to model the modulus of rupture (MOR) strength using Adaptive Learning Networks (ALN's) for aircraft engine components produced by a slip-cast, reaction-bonded, silicon-nitride production process. The primary objectives of the work were to identify key process variables and to predict optimum values for those variables as a guide for further experimentation. Nonlinear models have been synthesized that predict MOR with an average error of about 4 ksi over a range from 18.6 to 47.8.

The manufacturing and analysis work done to date has demonstated the feasibility of modeling the slip-cast RBSN process with the Adaptive Learning Network methodology and is viewed as the first iteration in the optimization procedure which is ultimately aimed at finding those manufacturing conditions which will produce the strongest, most consistent material strengths.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A program was conducted to model the modulus of rupture (MOR) strength using Adaptive Learning Networks (ALN's) for aircraft engine components produced by a slip-cast, reaction-bonded, silicon-nitride production process. The primary objectives of the work were to identify key process variables and to predict optimum values for those variables as a guide for further experimentation. Non-linear models have been synthesized that predict MOR with an average error of about 4 ksi over a range from 18.6 to 47.8.

The manufacturing and analysis work done to date has demonstrated the feasibility

of modeling the slip-cast RBSN process with the Adaptive Learning Network methodology and is viewed as the first iteration in the optimization procedure which is ultimately aimed at finding those manufacturing conditions which will produce the strongest, most consistent material strengths.

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1. INTRODUCTION

This work involves the Adaptive Learning Network (ALN) modeling of a slip-cast, reaction-bonded silicon-nitride (RBSN), ceramic production process. The primary objectives of the work are to identify the key parameters of the production process, to seek an optimum set of parameter values, and to develop control procedures which yield highest and most consistent part strengths.

1.1 THE ROLE OF MODELING IN PROCESS OPTIMIZATION

Optimization of the ceramics manufacturing process involves an experimental search for the ideal manufacturing conditions. Typically an iterative procedure is employed. At each round or iteration of the search procedure, several manufacturing experiments are performed. The experimenter then analyzes the results and, based on this analysis, formulates hypotheses on parameter regions which are projected to yield improved performance. These projections form the basis for designing the next round of experiments. The experimental results at each round serve to confirm or reject the hypotheses formed in earlier rounds and will influence further experimentation accordingly.

The efficiency and effectiveness of the search procedure is highly dependent upon the adequacy of the analysis function. Implicit in any analysis is the formulation of a model of the process. The model is the tool which gives the ability to predict future performance of the process based upon past observations.

Modeling has three primary roles in process optimization. First, it is used to guide the experimental search such that a minimum amount of experimental time, cost, and effort are incurred in converging on the optimum. Second, the modeling will reveal which variables are important, what their optimum values are, and to what tolerances they must be controlled. Third, if certain important variables have not been measured, model performance metrics will indicate that crucial information is missing, which will guide the experimenters in identifying additional variables to be instrumented in subsequent experiments.

1.1.1 Guiding the Search

Due to the expense and time of performing the laboratory experiments, it is desired that each experiment provide a maximum amount of new information about better manufacturing conditions. The procedure for designing the next experiment consists of two steps. First, the model is updated, or retrained, using all the data gathered to date. Secondly, the model is interrogated, or searched, for regions of highest predicted strength. The search is permitted to range somewhat beyond the region of data already collected, and typically the highest areas are outside the data regions. Though the model is not expected to be highly accurate outside the data regions, it is a good hypothesis that collection of further experimental data in the high areas will yield the most useful results. Subsequent experiments are then performed in these projected high regions.

The optimization process is complete when the peak operating conditions have been found. Three conditions must be satisfied to verify the peak. First, the model surface must exhibit a major peak or high region where any deviations from that area result in lower predicted strength. Secondly, all the regions on and surrounding the peak should be well supported by experimental data. Third, the accuracy of the model, as judged on the data immediately surrounding the peak, should be quite high, indicating that the model properly accounts for all key variables and adequately represents the process.

1.1.2 Determining Controls and Tolerances

Once the optimization is complete, the optimum values of the manufacturing parameters may be found by locating the model peak. Control tolerances are then determined by varying each parameter from its optimum value and observing the consequent effect on predicted strength.

Nonlinear variable interaction in the peak region should also be examined to determine whether a deviation on one parameter significantly varies the tolerance on another. Trade-off analyses may be undertaken to determine whether some non-optimum set point would produce less parameter sensitivity and thus more reliable results. These control analyses are performed by investigation of models and do not require further laboratory experimentation.

1.1.3 Finding Missing Information

If one or more crucial process parameters are not measured in the production experiments, there is no way for the modeling algorithm to identify them specifically. But, by an analysis of the accuracy of the models, it can be determined whether further information is needed to model the process accurately, and an estimate of the importance of that missing information can be obtained from the model errors. Knowledge of the need for further information is very useful to the experiment designer as he seeks to identify additional variables which must be measured. Highly accurate model performance is an indication that all the meaningful variables have been accounted for.

1.2 REQUIREMENTS OF THE MODELING ALGORITHM

The effectiveness of a process optimization procedure is highly dependent upon the power of the modeling algorithm. There are four key requirements on the modeling algorithm which are generally not fully met by conventional modeling approaches but which are met by the Adaptive Learning Network methodology.

1.2.1 Nonlinearity

When modeling a process for the purpose of optimization, the final model must embody a convex surface to represent the region of the optimum peak. A linear representation is not adequate because it has no finite optimum. In a polynomial expansion, a convex surface can be no less than a quadratic in each

input variable, and in many instances the degree may be higher. Processes such as ceramics manufacturing are very likely to have subtle but distinct nonlinear interactions between variables. The ALN method automatically considers higher order terms and nonlinear interactive terms for all candidate input variables.

1.2.2 Automatic Synthesis of Model Structure

In most conventional modeling approaches, the user selects the mathematical structure of the model, or a small set of possible structures, and the algorithm determines the coefficient values which produce the best fit to the data. Specifying a model structure for a process as complex as a ceramics manufacturing process is very difficult, and if the proper model structure is not chosen, the model accuracy will be poor no matter how good or complete the data is.

The ALN model synthesis algorithm automatically generates the model structure as well as the coefficient values.[1/] The routine generates its models by systematically incorporating only those polynomial terms and functions which provide the maximum performance improvement with minimum increased model complexity. The structure synthesis procedure thus automatically selects the most important process variables and defines, in mathematical terms, their relationships to material strength.

1.2.3 Prevention of Overfit

A trained model is said to be "overfitted" if it produces small errors on the data upon which it was trained but performs poorly on similar data that were not used in training. An overfitted model is thus not useful as a predictive tool which can forecast, with acceptable accuracy, what the results of a future experiment will be.

In process optimization, where prediction of the results of future experiments is important to the minimization of the number of experiments which are to be performed, and in control synthesis, where variable sensitivities must be accurately estimated, overfit must be minimized. Overfit generally occurs when the model is more complex than is statistically justified by the given data base.

On the other hand, it is desirable to obtain as much information from the data as possible to support a model of a complex process. The ALN algorithm employs information theoretic measures which permit the growth of model complexity up to but not beyond the extent justified by the given data base.

[1/] The ALN structure uses the form of a polynomial, rather than an exponential or some other transcendental form; however, the polynomial expansion is a very powerful, general representation that can mathematically approximate any continuous function.

1.2.4 Treatment of Limited Data Bases

Most conventional modeling approaches require more observations than there are variables. In the early stages of ceramics optimization, this situation does not exist. It is desirable to vary on the order of 100 factors but there may be only 25 to 50 experimental observations. In conventional experimental designs, only a few parameters are varied while all others are held constant. The ALN method can extract meaningful models from a limited data base, even when the number of varying parameters far exceeds the number of experimental observations.

In summary, the ALN modeling procedure is specifically suited for the non-linearity, unknown-structure, non-overfit, and limited-data requirements for optimization of complex processes.

1.3 SUMMARY OF WORK PERFORMED TO DATE

Laboratory work was performed by the Garrett Corporation on a slip-cast RBSN process to produce test bars under 35 different sets of manufacturing conditions. For each condition, the manufacturing parameters were recorded and test bars were destructively tested to obtain data on the resulting material strengths. The strength parameters were room-temperature modulus-of-rupture (MOR) and Weibul modulus. Adaptronics, Inc. performed the modeling analysis of the data.

In the course of the modeling, three types of models were synthesized. First, strength and strength variance were modeled as a function of the independent input variables, such as slip proportions and sintering temperatures. Second strength and strength variance were modeled as a function of the intermediate process variables, such as nitrided density and weight gain. Third, the intermediate process variables were modeled as a function of the independent inputs. The combination of these three sets of models shows the overall flow of effects through the production process. Actual material strengths varied from approximately 19 to 48 ksi, and the models predicted these strengths with an average error of 4 ksi over the total range of 29 ksi. Key process parameters and the means by which they influenced strength were identified.

The manufacturing and analysis work done to date has demonstrated the feasibility of modeling the slip-cast RBSN process with the Adaptive Learning Network methodology and is viewed as the first iteration in the optimization procedure which is ultimately aimed at finding those manufacturing conditions which will produce the strongest, most consistent material strengths.

2. DATA BASE

Process variables and resulting part strengths were recorded for 35 different production conditions. Approximately twenty test bars were manufactured at each condition, and the bars were destuctively stress-tested to determine their strengths in terms of room temperature modulus-of-rupture (MOR) and strength variance, which inversely is related to Weibul Modulus. For the work done to date, the strength resulting from a certain production condition is taken to be the average strength of the twenty test bars. A listing of the data base is presented in Appendix 1. From this listing, it can be seen which process variables were measured and/or computed as well as the numerical ranges of the variables.

The raw particle size distribution (PSD) data and the sintering and nitriding temperature histories are continuous curves. For use in modeling, discrete parameters of the curves must be computed. It is as crucial to compute "important" parameters from continuous data as it is to instrument any significant, but directly measurable, discrete variable. Discovering useful waveform parameters is often complicated due to the very large number of possibilities. In practice, several specific parameters from each of several categories are computed and input to an ALN training algorithm which selects the most useful of the parameters presented to it. Based on which variables are selected, knowledge of the physical process, and experience from other processes which may have some similarities, new parameters are formulated and tested in further ALN training. Ultimately it is desirable to reduce any curve to three or four key descriptors.

2.1 PARAMETERIZATION OF PARTICLE SIZE DISTRIBUTIONS

To begin the parameterization of the PSD curves, the cumulative distribution curves were differentiated and scaled to provide relative particle size density functions.

Twenty-six parameters (numbers 67 through 92 in the data base) were computed from the PSD curves. Five parameters indicated the percentage, by weight, of particles greater than specified sizes (40, 20, 10, 5, and 1 micrometer(s)). These percentage parameters were tantamount to evaluating the cumulative curves at specified size points. Five parameters indicated the particle size, in logarithmic form, for which specified percentage levels (20, 50, 80, 95, and 98) were achieved. These size parameters were tantamount to evaluating the cumulative curves at specified percentage points. The next parameter was the size of the largest particle found in a sample of the powder. Six parameters indicated the amount of weight in six adjacent size bins (.0 to .3, .3 to 1.0, 1.0 to 3.0, 3.0 to 10.0, 10.0 to 30.0, and above 30.0). Five parameters were the ratios of weights in the various bins. The final four parameters were the first four moment-generating functions indicating average, variance, skew, and kurtosis of the density function.

2.1.1 Modeling Strength as a Function of the PSD Parameters

When modeling strength from the above original PSD parameters, the variables that were selected by the networks were shape parameters, most particularly the second and fourth moment generating functions and the number of particles greater than 40 µm. The second moment is variance which indicates the spread or width of the distribution. The fourth moment is kurtosis, which is a rough indicator of uni- versus bi-modality of a curve.

Investigation into the models shows that high strengths are achieved with (a) a broad variance, (b) high kurtosis, i.e., uni-modality, and (c) no particles larger than 40 µm. These analyses are borne out by a visual inspection of the PSD curves. For this purpose, the PSD curves for the 14 powders are shown in Figure 2.1. The curves are arranged in order of their average resulting strengths. The first four curves, A_4B_6[1/] (top two), A_4B_9, and A_2B_6 produced the strongest parts, and each had the properties selected by the models. The very low strength curves were multimodal. The A_2B_7 curve had too small a spread.

2.1.2 Hypothesis of an Ideal Particle Size Distribution

From the above results, it was hypothesized that an ideal particle size distribution would be of the form:

$$p(s) = As^n \exp\left[-\frac{n}{m}\left(\frac{s}{a}\right)^m\right] \qquad (1)$$

where

- s = particle size
- p(s) = particle size distribution
- A = normalization scale factor
- a = value of s at which p(s) peaks
- n = constant controlling the rise rate of p(s)
- m = constant controlling the fall rate of p(s)

This curve is unimodal, which accounts for the kurtosis constraint, but the coefficients a, n, and m permit a range of shapes to fit the "good" PSD curves.

2.1.3 Fitting the Distributions

The first step in testing the ideal distribution hypothesis involved fitting the actual particle-size distributions with the postulated formula and finding the coefficients a, n, and m which gave the least-squares error fit to each of the actual distributions. The curve fitting approach employed a gradient accelerated search to find the optimum values of the coefficients a, n, and m.

[1/] Letters A, B, D, F, and G indicate subprocesses: A - starting powder, B - powder preparation, D - slip preparation, F - sintering, and G - nitriding. The subscripts indicate the manufacturing condition number. Thus A_2B_6 indicates the second starting powder processed by the sixth procedure. The specific condition parameters are given in the Appendix.

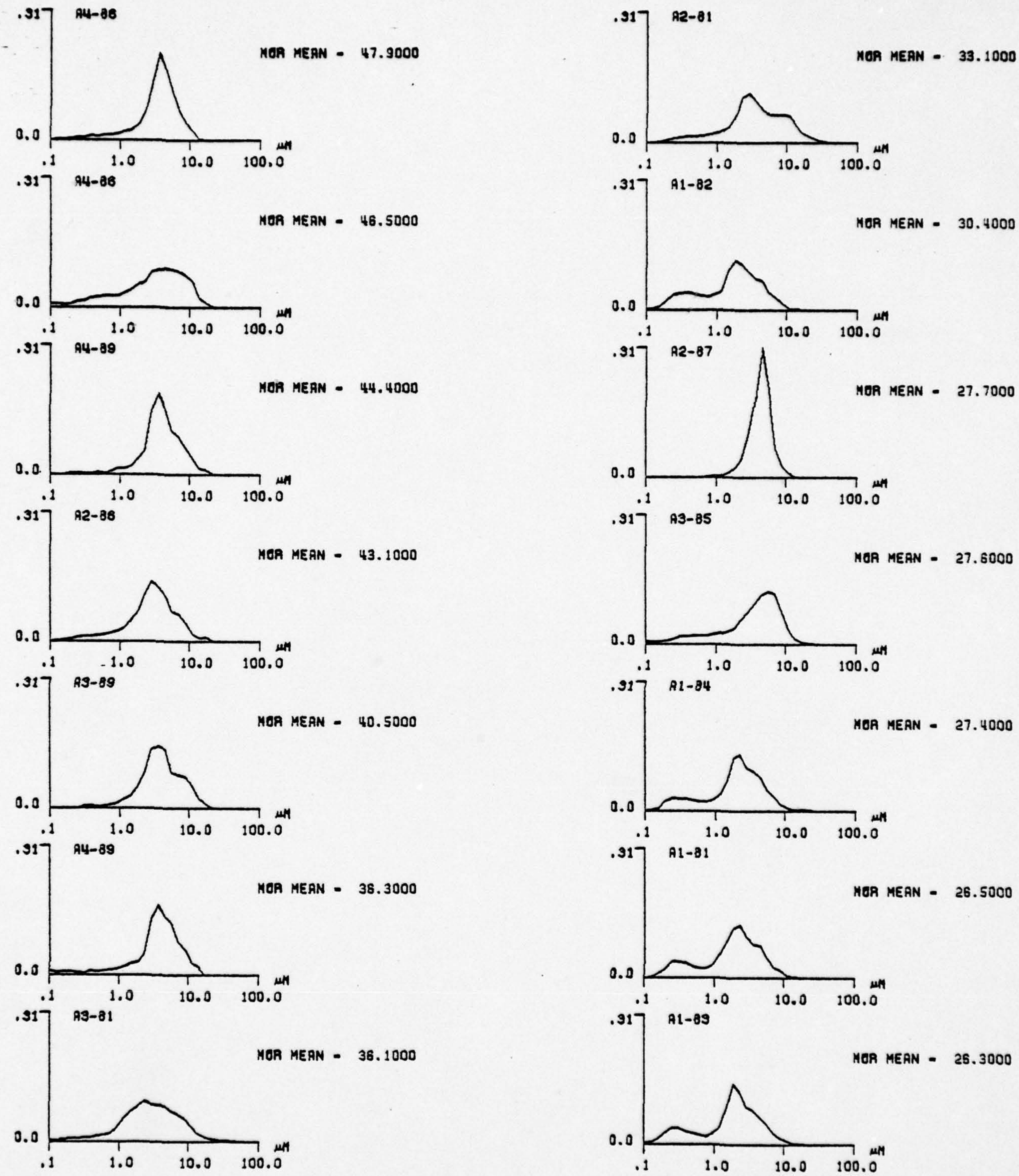


FIGURE 2.1: ACTUAL PARTICLE SIZE DISTRIBUTIONS AND CORRESPONDING VALUES FOR MEAN STRENGTH, SHOWN IN ORDER OF MEAN RESULTING STRENGTH

A gradient search was selected over a regression fitting approach because of the difficulty of linearizing the theoretical formula. The optimum coefficient values are considered to be those which produce the minimum total deviation between the postulated and actual curves. The total deviation, or fitting error, is defined to be the sum of the squares of the density differences between the two curves at each point along the size axis.

2.1.4 The Gradient Accelerated Search Algorithm

The starting values of a, n, and m are nominal values which are the same for each actual distribution. This starting point, and the resulting error, is initially defined to be the best-to-date, and the error gradient is computed at that point. To find the next trial point, a step is then taken from the best-to-date point along the gradient vector. The size of the first step is user-specified and is small. The resulting theoretical curve is compared to the actual distribution, and the fitting error is computed. If the resulting error is reduced, the trial point becomes the best-to-date.

Rather than recomputing the gradient and moving in a new direction, the next step is taken along the original gradient. The step is taken from the new best-to-date point but the step size is doubled (acceleration). Motion continues along the same gradient line with the step size continually doubling until the performance no longer improves. The search then returns to the most recent best-to-date point, computes a new gradient vector, resets the step size to the original small value, and proceeds along the new gradient vector.

The search is stopped when the first (small) step along a newly computed gradient vector does not produce an improvement. The search is then within one small step of the peak, which is considered to be sufficiently close.

The acceleration feature of the search allows small steps to be taken to pinpoint the peak, but avoids the excessive computation time of a fixed-step-size search which always "creeps" along.

A potential problem with gradient searches is that they can get "trapped" on local non-optimum peaks. It has been established that the search space for the particle-size distributions is unimodal over the region of interest so there is no problem of identifying the global peak.

2.1.5 Fitting Results

The theoretical curves fitted to each of the fourteen actual particle-size distributions are shown by the heavy lines in Figure 2.2. Table 1 gives the values of the coefficients which were found, the residual error resulting from the optimum fit, and the strengths of the test bars which were manufactured from the powder.

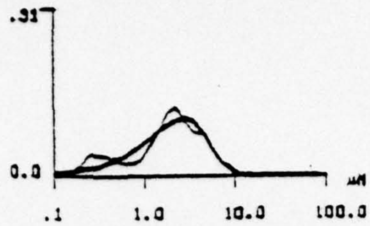
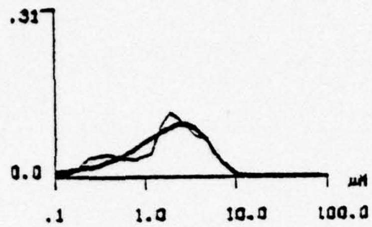
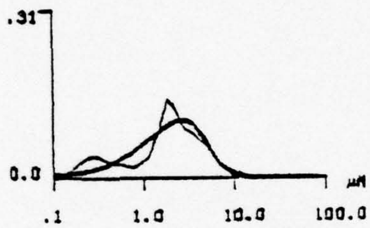
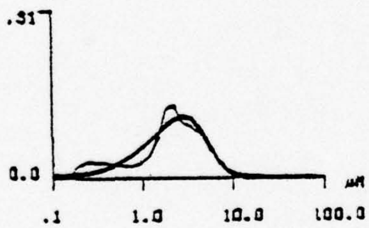
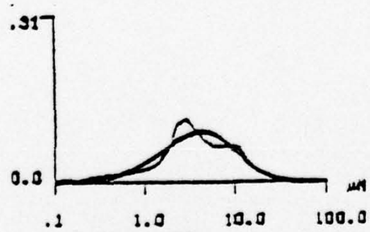
An analysis of these data shows that the psd's which yield high strength typically have high values of n accompanied by low values of m, which indicates that excessive amounts of powder below .3 μM and above 20.0 μM are undesirable. Also, those psd's which can be fitted closely by the theoretical curve result in higher ceramic strengths than those curves which cannot be fitted well. This tends to support the hypothesis that such a curve is ideal.

TABLE 2.1: PARTICLE SIZE DISTRIBUTION
FITTING COEFFICIENTS

Powder Number	Condition Numbers	Fitted Coefficient Values a,	n,	m,	n/m	RMS Fitting Error	Strengths (MOR) mean	min	max
A_1B_1	1-11	3.63	1.09	1.50	0.73	.107	26.5	18.6	33.3
A_1B_2	12-15	3.55	0.90	1.52	0.59	.103	30.4	26.8	39.3
A_1B_3	16-17	3.63	1.13	1.47	0.76	.124	26.3	24.6	28.0
A_1B_4	18-20	3.89	1.25	1.52	0.82	.113	27.4	25.9	29.4
A_2B_1	21	5.88	2.36	0.47	5.02	.103	33.1	33.1	33.1
A_2B_6	22-25, 30	4.68	3.49	0.59	5.91	.089	43.1	41.4	45.0
A_2B_{17}	26	6.61	3.81	3.16	1.21	.091	27.7	27.7	27.7
A_3B_1	27	4.57	3.05	0.37	0.68	.068	36.1	36.1	36.1
A_3B_5	28-29	8.31	0.96	3.04	0.31	.071	27.6	27.1	28.0
A_3B_9	31	17.72	.79	1.8Ø	.44	.Ø15	4Ø.5	26.Ø	46.7
A_4B_6	32	18.85	.79	1.80	.44	.ØØ4	46.5	4Ø.5	5Ø.2
A_4B_9	33	17.84	3.91	.75	5.21	.Ø12	36.3	15.9	56.Ø
A_4B_6	34	17.52	5.Ø	.85	5.88	.Ø12	47.9	39.Ø	54.7
A_4B_9	35	17.69	5.Ø	.67	7.46	.Ø13	44.Ø	39.8	48.5

Fitted Distribution: $p(s) = A\, s^n \exp[-n/m(s/a)^m]$

s = article size
p(s) = particle size distribution
A = normalization scale factor
a = value of s at which p(s) peaks
n = constant controlling rise rate of p(s)
m = constant controlling fall rate of p(s)

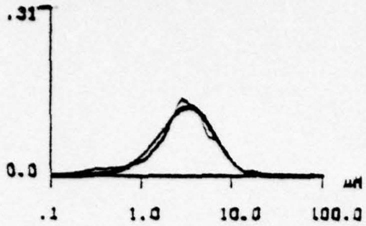
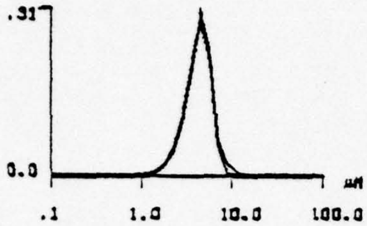
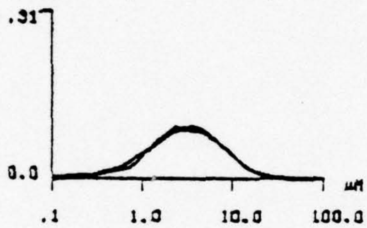
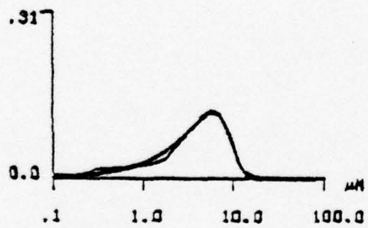
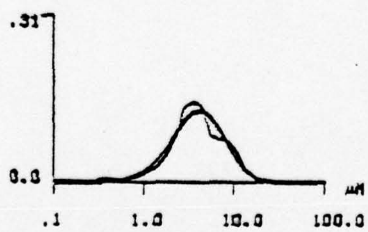
PARTICLE SIZE DISTRIBUTION (PSD)	PROCESS NUMBERS	CONDITION NUMBERS	STRENGTHS
	A1-B1	1-11	MOR MEAN = 28.5000 MIN. = 18.6000 MAX. = 33.3000
	A1-B2	12-15	MOR MEAN = 30.4000 MIN. = 28.8000 MAX. = 34.3000
	A1-B3	16-17	MOR MEAN = 26.3000 MIN. = 24.6000 MAX. = 28.0000
	A1-B4	18-20	MOR MEAN = 27.4000 MIN. = 25.9000 MAX. = 29.4000
	A2-B1	21	MOR MEAN = 33.1000 MIN. = 33.1000 MAX. = 33.1000

Size

Heavy Line: Fitted PSD   Narrow Line: Actual PSD

FIGURE 2.2: ACTUAL AND FITTED PARTICLE SIZE DISTRIBUTIONS FOR THE 14 POWDERS USED IN THE 35 EXPERIMENTS

(continued)

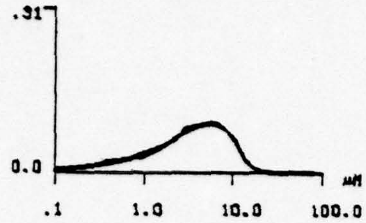
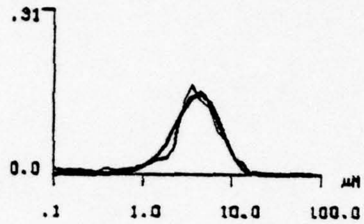
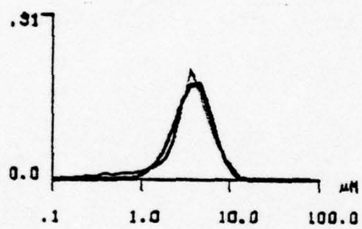
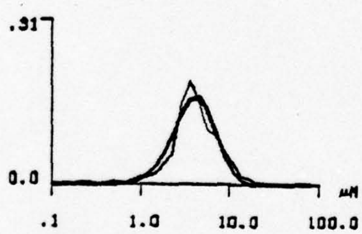
PARTICLE SIZE DISTRIBUTION (PSD)	PROCESS NUMBERS	CONDITION NUMBERS	STRENGTHS
	A2-88	22-25, 30	MOR MEAN = 43.1000 MIN. = 41.4000 MAX. = 45.0000
	A2-87	26	MOR MEAN = 27.7000 MIN. = 27.7000 MAX. = 27.7000
	A3-81	27	MOR MEAN = 36.1000 MIN. = 36.1000 MAX. = 36.1000
	A3-85	28-29	MOR MEAN = 27.8000 MIN. = 27.1000 MAX. = 28.0000
	A3-89	31	MOR MEAN = 40.5000 MIN. = 28.0000 MAX. = 48.7000

Size

Heavy Line: Fitted PSD Narrow Line: Actual PSD

FIGURE 2.2: ACTUAL AND FITTED PARTICLE SIZE DISTRIBUTIONS FOR THE 14 POWDERS USED IN THE 35 EXPERIMENTS

(continued)

PARTICLE SIZE DISTRIBUTION (PSD)	PROCESS NUMBERS	CONDITION NUMBERS	STRENGTHS
	A4-88	32	MOR MEAN = 48.5000 MIN. = 40.5000 MAX. = 50.2000
	A4-89	33	MOR MEAN = 38.3000 MIN. = 15.9000 MAX. = 56.0000
	A4-86	34	MOR MEAN = 47.9000 MIN. = 39.0000 MAX. = 54.7000
	A4-89	35	MOR MEAN = 44.4000 MIN. = 39.8000 MAX. = 48.5000

Size

Heavy Line: Fitted PSD

Narrow Line: Actual PSD

FIGURE 2.2: ACTUAL AND FITTED PARTICLE SIZE DISTRIBUTIONS FOR THE 14 POWDERS USED IN THE 35 EXPERIMENTS

2.2 PARAMETERIZATION OF THE SINTERING AND NITRIDING TEMPERATURE PROFILES

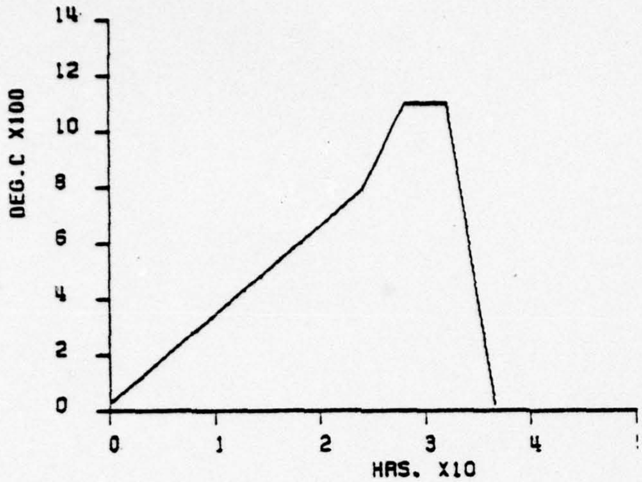
Seven different sintering runs and three different nitriding runs were used among the 35 production conditions. The temperature-versus-time profiles of the sintering and nitriding runs are shown in Figures 2.3 and 2.4 respectively, with the resulting average strengths are shown on the right of the Figures.

2.2.1 Sintering Profile Parameters

Fourteen parameters (numbers 113 through 136 in the data base) were computed from each of the seven sintering temperature profiles. The first six parameters are the duration times that the sintering temperatures were above specified temperatures (200°, 400°, 600°, 800°, 900°, and 1000°C). The next six parameters are the degree hours above the (same) specified temperatures, i.e., the areas under the curve and above the threshold temperature. The final two parameters are the rise and fall times between 21° and 900° C.

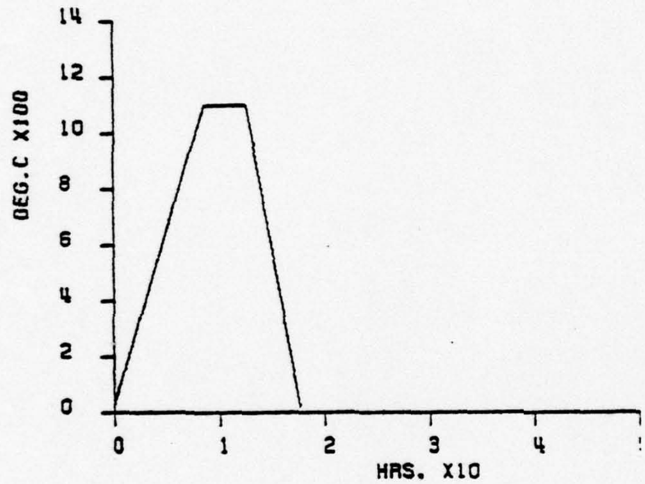
2.2.2 Nitriding Profile Parameters

Fourteen parameters (numbers 141 through 154 in the data base) were computed from each of three nitriding temperature profiles. The parameters are the same as the sintering variables except that the specified temperature levels were 400, 600, 800, 1000, 1200, and 1300 °C. No rise or fall times wee computed as these were very rapid with respect to the overall nitriding times.



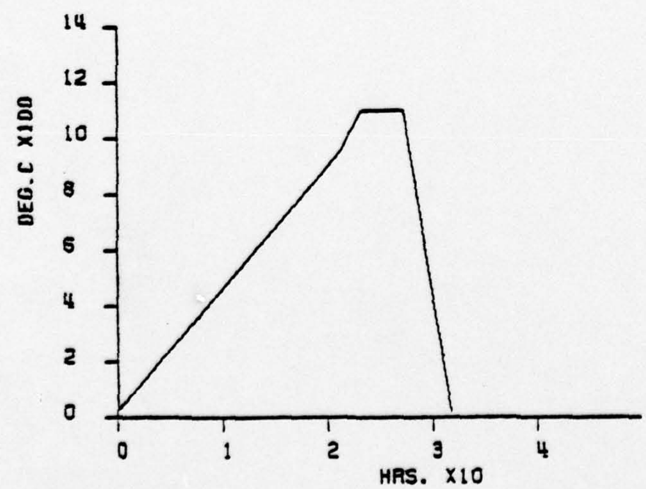
Condition Numbers

1.6, F, 13, 16, 18, 19, 21, 22, 25, 27, 28
MOR MEAN = 31.6000
MIN. = 23.2000
MAX. = 45.5000



Condition Number 26

MOR MEAN = 27.700
MIN. = 27.7000
MAX. = 27.7000

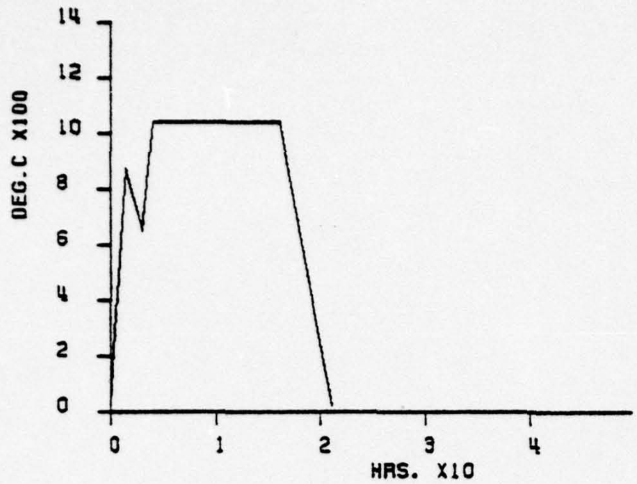


Condition Numbers

2, 3, 8, 9, 12, 14, 17, 23
MOR MEAN = 28.8000
MIN. = 21.0000
MAX. = 41.8000

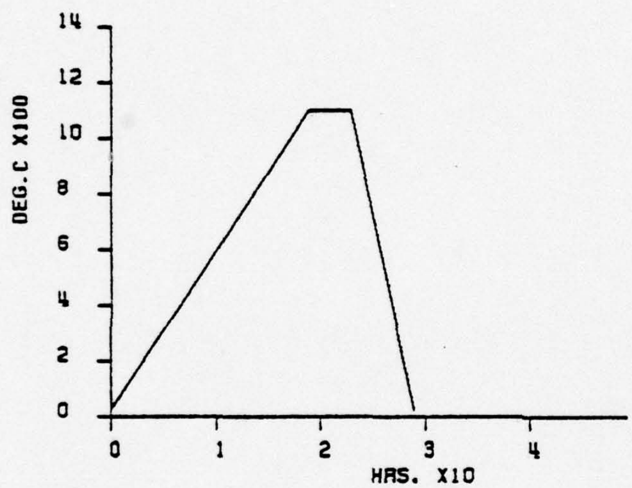
FIGURE 2.3: TEMPERATURE VS. TIME PROFILES FOR THE SINTERING PROCESS

(continued)



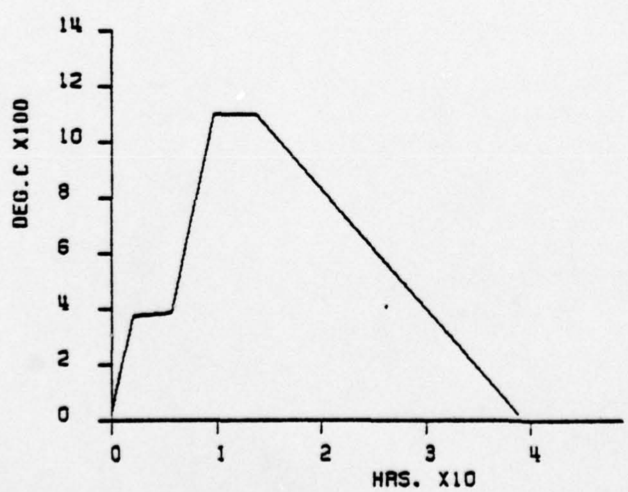
Condition Numbers

4, 5, 10, 11, 15, 20, 24, 29
MOR MEAN = 29.3000
MIN. = 18.6000
MAX. = 41.4000



Condition Numbers 30, 31

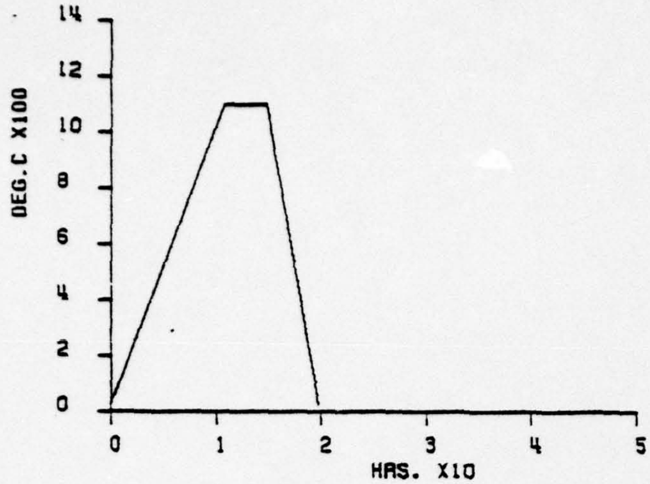
MOR MEAN = 42.1500
MIN. = 40.5000
MAX. = 43.8000



Condition Numbers 32, 33

MOR MEAN = 41.5500
MIN. = 36.6000
MAX. = 46.5000

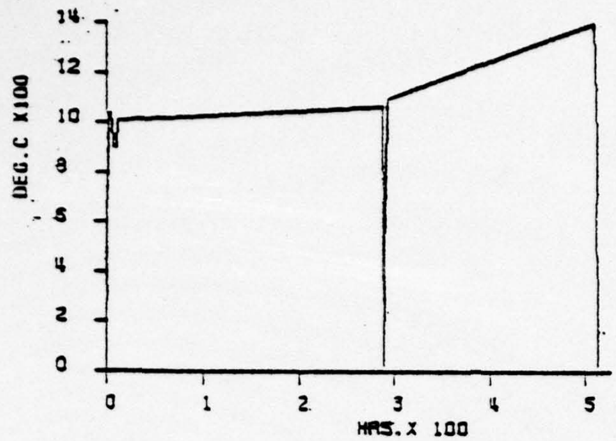
FIGURE 2.3 (continued)



Condition Numbers 34, 35

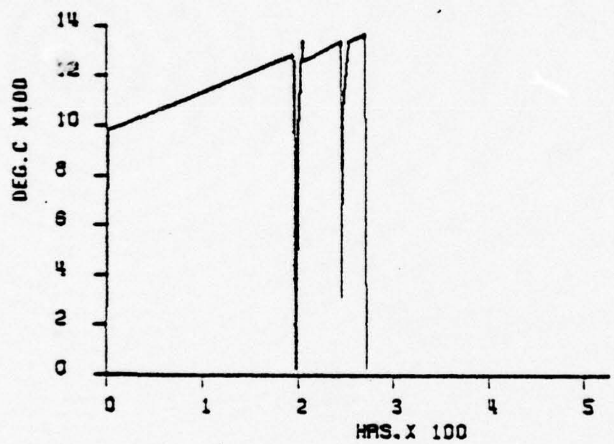
MOR MEAN = 46.1000
MIN. = 44.3000
MAX. = 47.9000

FIGURE 2.3 (continued)



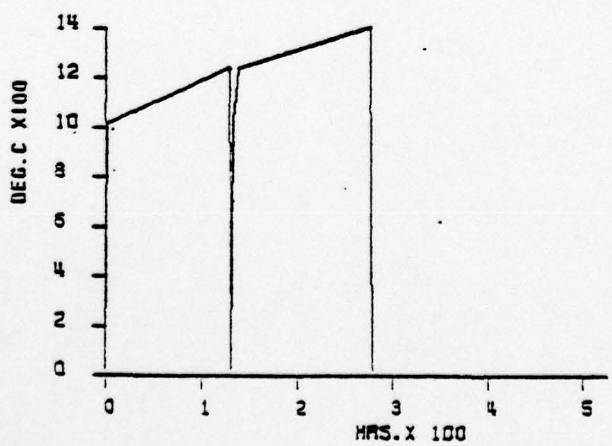
Condition Numbers 1-29

MOR MEAN = 30.1
MIN. = 18.6
MAX. = 45.0



Condition Numbers 30-33

MOR MEAN = 41.2
MIN. = 36.6
MAX. = 46.5



Condition Numbers 34-35

MOR MEAN - 46.1
MIN. = 44.3
MAX. = 47.9

FIGURE 2.4: TEMPERATURE VS. TIME PROFILES FOR THE NITRIDING PROCESS

3. ADAPTIVE LEARNING NETWORK MODELING

3.1 ALN MODELS

Several ALN models of the ceramics manufacturing process were generated using the Adaptronics, Inc. PNETTR(3) model synthesis algorithm. The models discussed here were trained using all 35 data points provided by AiResearch. Three categories of models were developed: (1) strength and strength variance were modeled as a function of the independent process input variables, (2) strength and strength variance were modeled as a function of dependent intermediate process variables, and (3) the dependent intermediate process variables were modeled as a function of the independent process input variables.

Figures 3.1a through 3.12a show the models from each of the three respective categories. All model inputs and outputs have been linearly scaled to zero mean and unit standard deviation (see Appendix 1 for scaling factors) to allow an evaluation of relative variable importance by comparison of coefficient magnitudes. The predominant mathematical terms of the models, in unitized partial derivative form, are shown along with the network block diagrams. These partial derivatives are quantitative estimates of the relationships between variables.

Also shown in each ALN figure are the ranges, R, of values over which the models were trained, the standard deviation, S, of the data, and the RMS error that the models produced. There are two error metrics. The first is the RMS error, e, that was obtained on the 35 data points used in training, and the second is the RMS error, E, that the model would be expected to make on new data which was not used in the training process, E. Model usefulness should be judged by the second metric, the expected error. It must be emphasized that the expected error is a valid estimate only if the new data presented to the model is statistically similar to the original training data, i.e., that the values of the input and output variables are within the range of the training data. The model performance measure, $P = 1-E/S$, is unity minus the ratio the expected error on new data to the standard deviation of the original data. If this number is equal to zero, the model is of no value; if it is equal to unity, the model is a perfect predictor.

To provide visual insight to the models, contour plots of the ALN's are presented in Figures 3.1b through 3.12b. These diagrams show each network's output as a function of its two most predominant inputs. If a model has more than two inputs, the values of those inputs, for plotting purposes, are held constant at their mean value. The curves on the plots show contours of constant model output, and the numbers next to the curves indicate the model output value.

The asterisks on the contour diagrams show the locations of the 35 data points used in the model synthesis. Models are expected to be most accurate in the vicinity of the data and less accurate further away from the data. There are not always 35 asterisks on each plot. In many cases several observations had identical values for the two parameters being plotted, so an asterisk may represent several points.

3.2 MODEL INTERPRETATIONS

Investigation of the model structures leads to the following hypotheses about the slip-cast, reaction-bonded silicon-nitride manufacturing process. Because of the small amount of data used in the model synthesis, these interpretations should be viewed as no more than hypotheses about the process. It is intended that the interpretations be used only as guides for further experimentation and not as definitive statements about the chemical process.

3.2.1 Mean Strength Modeled as a Function of the Independent Variables: (Figures 3.1 and 3.2)

The presence of oxygen in the starting powder has a detrimental effect on strength; therefore a low amount (less than 0.5 percent) of oxygen in the starting powder is desirable.

The use of larger amounts of media quantity (above 10 Kg Al_2O_3) in the powder preparation has a positive effect on the ultimate ceramic strength.

Increasing the number of particles greater than 40 m generally reduces strength. There are two notable exceptions to this trend as shown by the A_2B_1 and A_3B_1 powders in Figure 3.2b. Both of these had approximately one percent of the particles greater than 40 m yet still achieved actual strengths of 33 and 36 ksi respectively, and these two data points account for the quadratic term in model. But the majority of the data lies to the left on the plot, with less than 0.33% of particles greater than 40 m, and in this region it is apparent that smaller percentages of large particles contribute to higher strength.

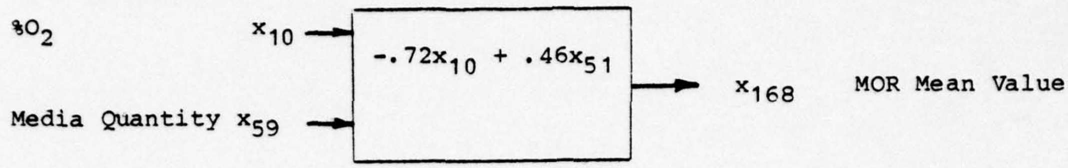
Increasing the standard deviation, or spread, of the particle size distribution has a minor positive effect on strength. Very narrow distributions should be avoided.

3.2.2 Strength Variance Modeled as a Function of the Independent Variables: (Figure 3.3)

Decreasing the rise coefficient (n) of the fitted particle size distribution tends to decrease strength variance. Lowering n corresponds to increasing the proportion of smaller particles in the overall size distribution and is in keeping with the requirement for a broad particle size distribution.

Increasing the coefficient of skewness of the particle size distribution tends to reduce the strength variance. Thus, though the total distribution should be relatively broad and its mean shifted twoard the smaller sizes, its shape should be skewed toward the larger sizes.

Shorter sintering times (less than 10 hours) at temperatures greater than 900°C appear to decrease the strength variance.

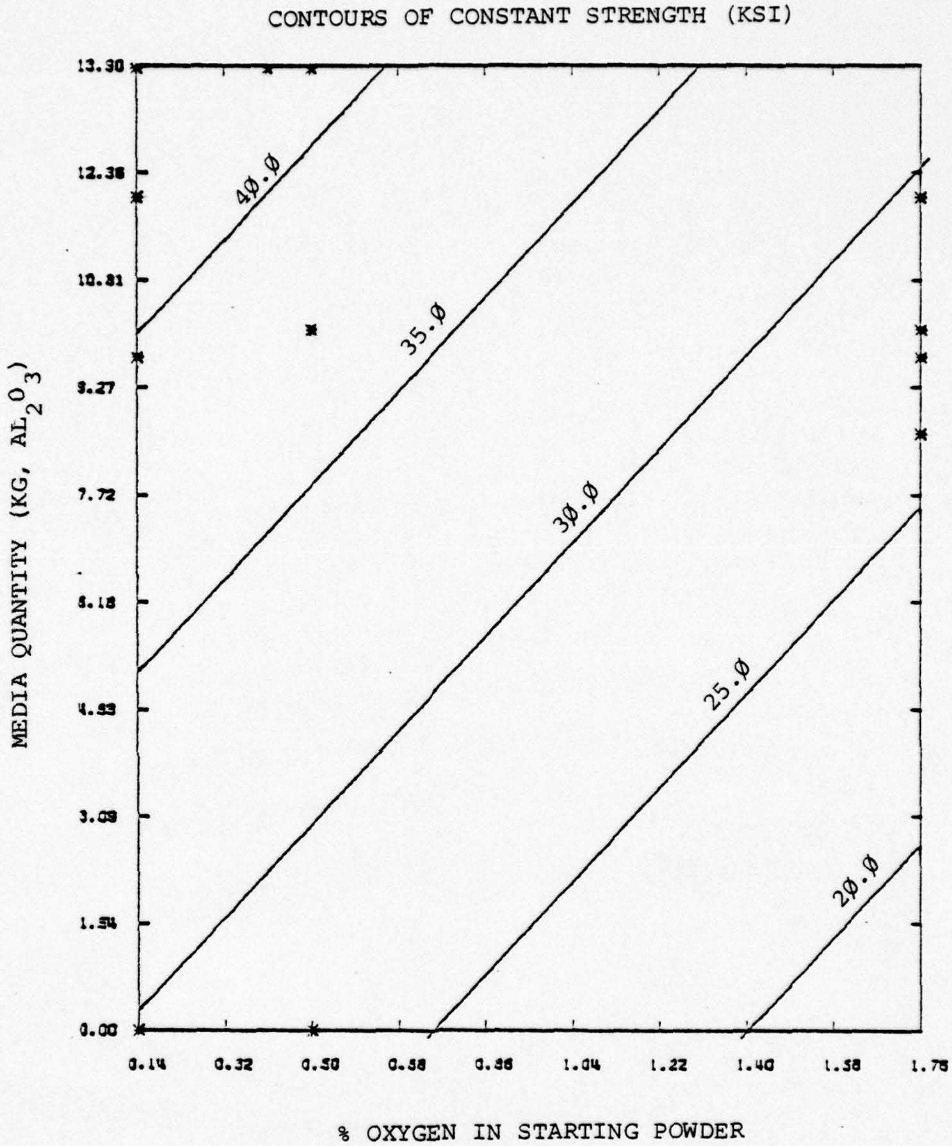


(R)	Range of the Data	: 29.1 (ksi)	Min = 18.69, Max = 47.80
(S)	Standard Deviation	: 7.82 (ksi)	
(e)	RMS Error on Training Data Base	: 3.88 (ksi)	
(E)	Expected RMS Error on New Data	: 4.6 (ksi)	
(P)	Model Performance Measure (1-E/S)	: 0.41	

Partial Derivatives of Mean MOR with Respect to the Model Input Variables:

Oxygen in Starting Powder (%)	:-7.71 (ksi/%)
Media Quantity (AL_2O_3,kg)	: 1.03 (ksi/kg)

FIGURE 3.1a: ALN MODEL PREDICTING STRENGTH AS A FUNCTION OF INDEPENDENT VARIABLES



* - indicates location of training data

FIGURE 3.1b: CONTOURS OF STRENGTH PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

% > 40 m x_{73} →

$$-.45 - 1.26x_{73} + .45x^2_{73} + .25x_{90}$$ → X168 MOR Mean Value

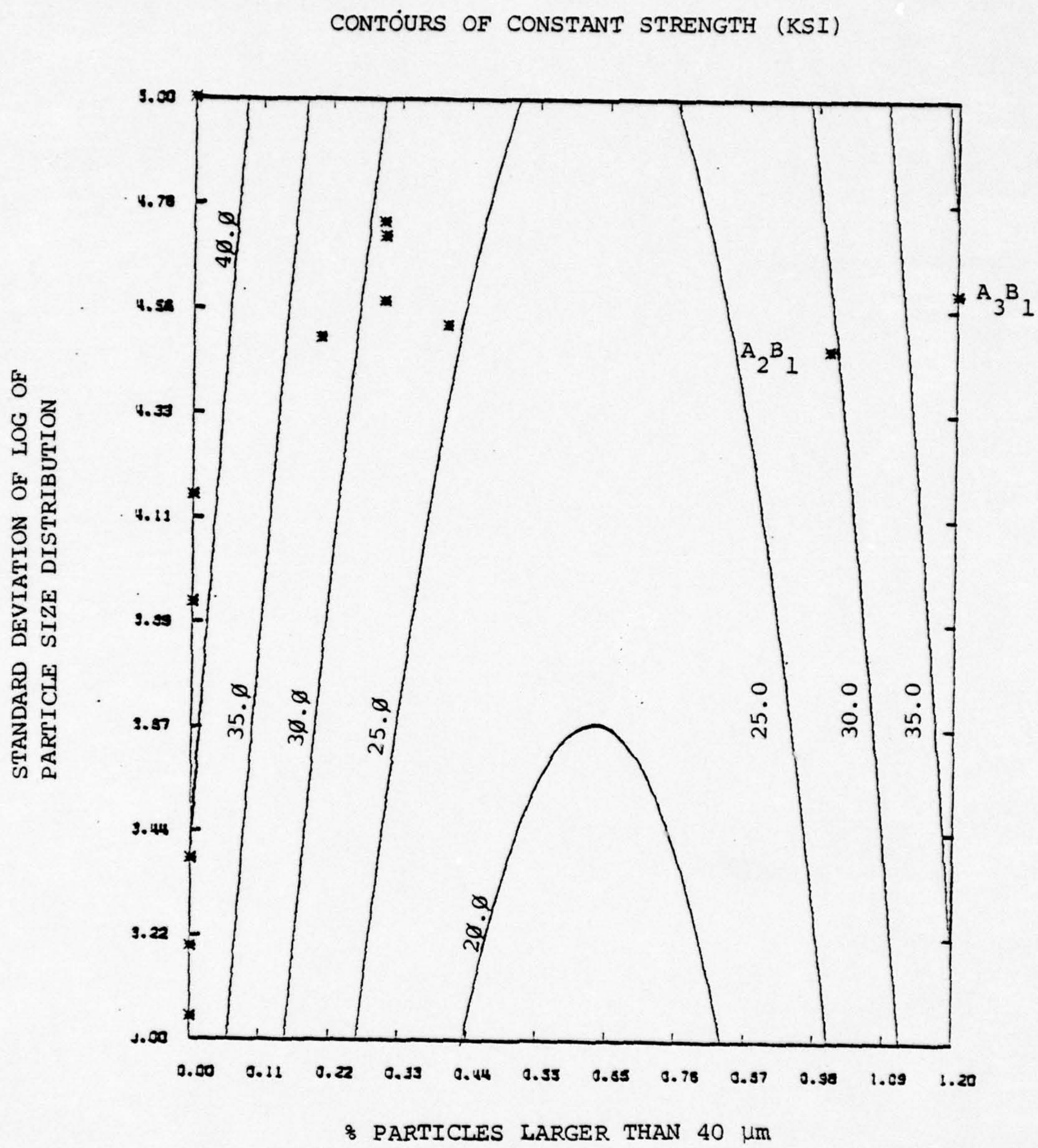
Stand. Dev. PSD x_{90} →

(R)	Range of the Data	: 29.1 (ksi)	Min = 18.69 Max = 47.80
(S)	Standard Deviation	: 7.82 (ksi)	
(e)	RMS Error on Training Data Base	: 4.17 (ksi)	
(E)	Expected RMS Error on New Data	: 5.14 (ksi)	
(P)	Model Performance Measure (1-E/S)	: .34	

Partial Derivative of MOR Mean with Respect to the Model Input Variables:

Percent Greater than 40 μm	:-37.90 (ksi/%)
Standard Deviation of log of PSD	: 3.15 (ksi/ M)

FIGURE 3.2a: ALN MODEL PREDICTING STRENGTH AS A FUNCTION OF PARTICLE SIZE DISTRIBUTION PARAMETERS



* - indicates location of training data

FIGURE 3.2b: CONTOURS OF STRENGTH PLOTTED AS A FUNCTION OF PARTICLE SIZE DISTRIBUTION PARAMETERS

PSD Rise Coeff. $x_{96} \rightarrow$

Time > 900°C Hrs (Sintering) $x_{117} \rightarrow$

Skewness $x_{91} \rightarrow$

$$.5x_{96} + .75x_{117} - .59x_{91} - .29x_{117}x_{96} - .95x^2_{117} - .26x_{96}x_{91} - .39x_{117}x_{91} + .15x_{117}x_{96}x_{91} + .49x^2_{117}x_{91} + .85$$

$\rightarrow x_{169}$ MOR Standard. Deviation

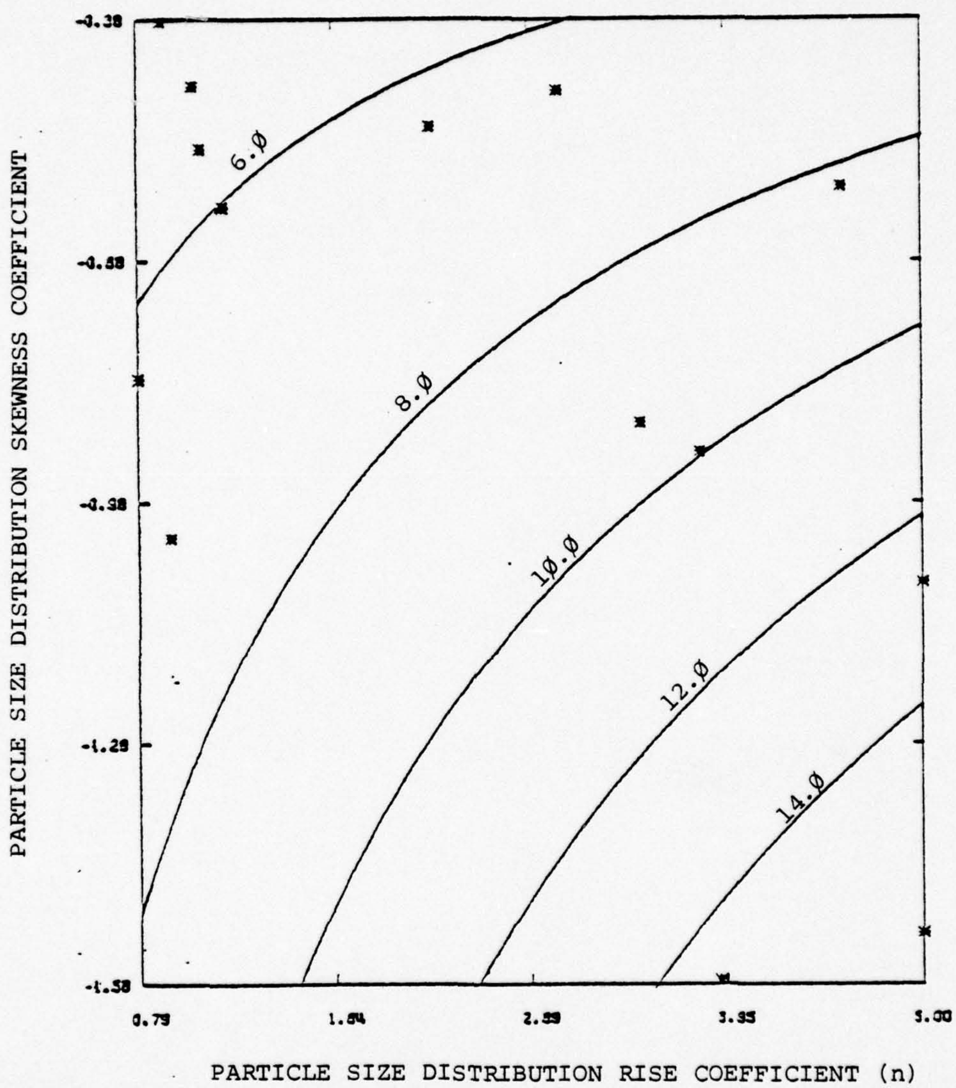
(R)	Range of the Data	:	10.82 (ksi); Min = 2.84, Max = 13.66
(S)	Standard Deviation	:	2.19 (ksi)
(e)	RMS Error on Training Data Base	:	1.22 (ksi)
(E)	Expected RMS Error on New Data	:	1.70 (ksi)
(P)	Model Performance Measure (1-E/S)	:	0.22

Partial Derivatives of MOR Standard Deviation with Respect to the Model Input Variables:

Fitted PSD Rise Coefficient (B)	: .81 (ksi)
Coefficient of Skewness	:-.73 (ksi)
Sintering Time Greater Than 900°C Hrs	: .68 (ksi/°C Hrs)

FIGURE 3.3a: ALN MODEL PREDICTING STRENGTH VARIANCE AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT VARIANCE (KSI^2)



* - indicates location of training data

FIGURE 3.3b: CONTOURS OF STRENGTH VARIANCE PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

3.2.3 Mean Strength Modeled as a Function of the Intermediate Process Variables: (Figure 3.4)

High strength results from high nitrided density and high weight gain during the nitriding process. As would be expected from a chemical analysis, the weight gain should approach the theoretical maximum of approximately 62%. The nitrided density would ideally be above 2.75 gm/cm^3.

Low percentages of Alpha-Silicon-Nitride (less than 75 percent) in the final analysis yield high strength.

3.2.4 Strength Variance Modeled as a Function of the Intermediate Process Variables (Figure 3.5)

Decreasing the ratio of Silicon Oxy-Nitride to Alpha-Silicon-Nitride tends to decrease strength variance.

Decreasing the ratio of Beta- to Alpha-Silicon Nitride appears to decrease strength variance if the ratio is .25 or higher to start with. Decreasing this ratio implies increasing Alpha which (from Section 3.2.3) would reduce strength, so it appears that there is a small tradeoff between strength and variance. Since low Alpha has a greater positive effect on strength than it has an adverse effect on variance, it is recommended that Alpha be minimized.

Decreasing the 1/30 viscosity appears to reduce strength variance to a small degree.

3.2.5 Intermediate Process Variables as a Function of the Independent Variables:

Slip pH: (Figure 3.6)

Slip pH appears to be highly nonlinearly dependent upon percent of solids in the slip and the percent of manganese in the starting powder. The model is quite biased, however, by observation number 26, which came from the A_2B_{17} powder, had an extremely low solids content of 52%, and resulted in a moderately low mean strength of 27.7 ksi.

Green Density: (Figure 3.7)

Increasing the percentage of slip additive NH_4OH results in increased Green Density.

For values between 0.00 and 0.04 percent, the amount of deflocculant does not significantly affect green density, but above about 0.04 percent, additional defloculant appears to increase Green Density.

Increasing the quantity of milling medium AL_2O_3 and increasing the slip aging time both cause minor increases in the Green Density of the parts.

% Wt. Gain $x_{155} \rightarrow$

Nitrided Dens. $x_{156} \rightarrow$ $\boxed{.37x_{155} + .25x_{156} - .61x_{157}}$ $\rightarrow x_{168}$ MOR Mean Value

Alpha $x_{157} \rightarrow$

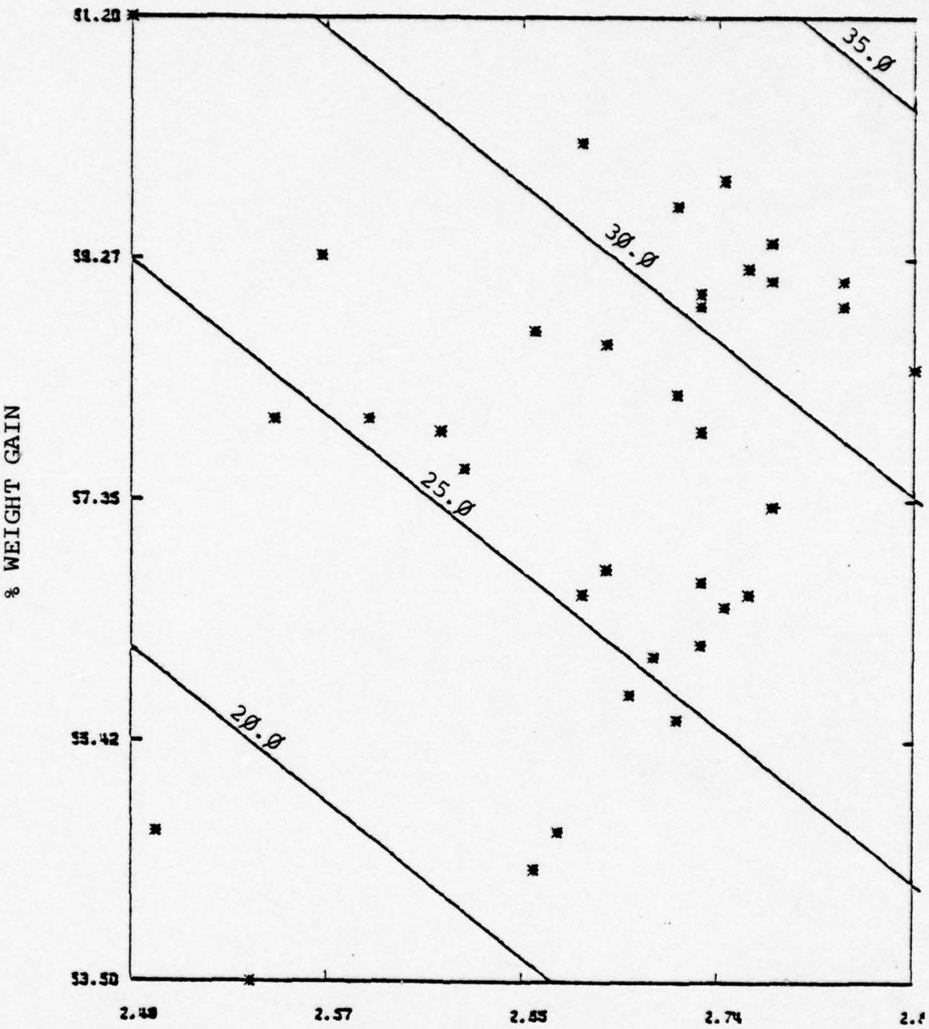
(R)	Range of the Data	: 29.1 (ksi) Min = 18.69, Max = 47.80
(S)	Standard Deviation	: 7.82 (ksi)
(e)	RMS Error on Training Data Base	: 3.59 (ksi)
(E)	Expected RMS Error on New Data	: 4.72 (ksi)
(P)	Model Performance Measure (1-E/S)	: 0.40

Partial Derivatives of Mean Strength with Respect to Model Input Variables:

Nitrided Density (gm/cm^3)	: 24.4 (ksi/(gm/cm^3)
Weight Gain (%)	: 1.63 (ksi/%)
Alpha (Rel. %)	:- 0.80 (ksi/%)

FIGURE 3.4a: ALN MODEL PREDICTING MEAN STRENGTH AS A FUNCTION OF INTERMEDIATE PROCESS VARIABLES

CONTOURS OF CONSTANT STRENGTH (KSI)



NITRIDED DENSITY (GM/CM^3)

* - indicates location of training data

FIGURE 3.4b: CONTOURS OF STRENGTH PLOTTED AS A FUNCTION OF INTERMEDIATE PROCESS VARIABLES

Viscos 1/30 x_{107}

Beta/Alpha x_{162}

Si_2ON_2/Alpha x_{163}

$$.47 + .81x_{107} + .70x_{162} + .31x_{163} - .11x^2_{162} + .4x_{107}x_{162} - .4x_{107}x^2_{162} - .34x^3_{162} \quad .25x^2_{107} + .15x^4_{162}$$

x_{169}

Standard Deviation

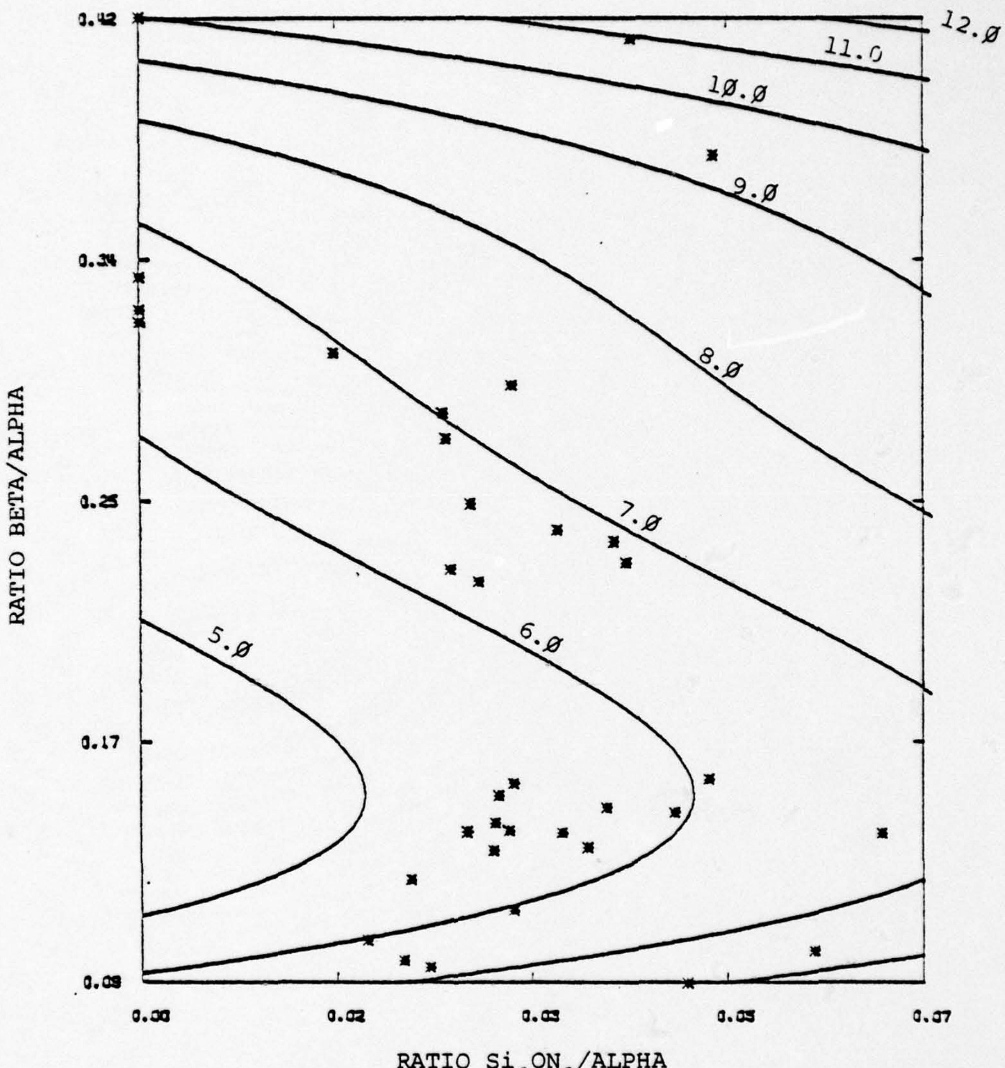
(R)	Range of the Data	: 10.82 (ksi)	Min = 2.84 Max = 13.66
(S)	Standard Deviation	: 2.19 (ksi)	
(e)	RMS Error on Training Data Base	: 1.23 (ksi)	
(E)	Eexpected RMS Error on New Data	: 1.63 (ksi)	
(P)	Model Performance Measure (1-E/S)	: 0.26	

Partial Derivatives of MOR Standard Deviation with Respect to the Model Input Variables:

Ratio Si_2ON_2/Alpha (%/%)	: 33.95 (ksi)
Ratio Beta/Alpha (%/%)	: 8.76 (ksi)
Viscosity 1/30 (CPS)	: 0.02 (ksi/CPS)

FIGURE 3.5a: ALN MODEL PREDICTING STRENGTH VARIANCE AS A FUNCTION OF INTERMEDIATE PROCESS VARIABLES

CONTOURS OF CONSTANT VARIANCE (KSI)



* - indicates location of training data

FIGURE 3.5b: CONTOURS OF STRENGTH VARIANCE PLOTTED AS A FUNCTION OF INTERMEDIATE PROCESS VARIABLES

%M_n $x_5 \rightarrow$ | Solids Content $x_{98} \rightarrow$

$$x_{105}\ (\text{pH}) = 2.17 - 2.58x_5 - 1.52x_{98} + 5.22x_5x_{98} - 1.18x_5^2 - 1.31x_{98}^2$$

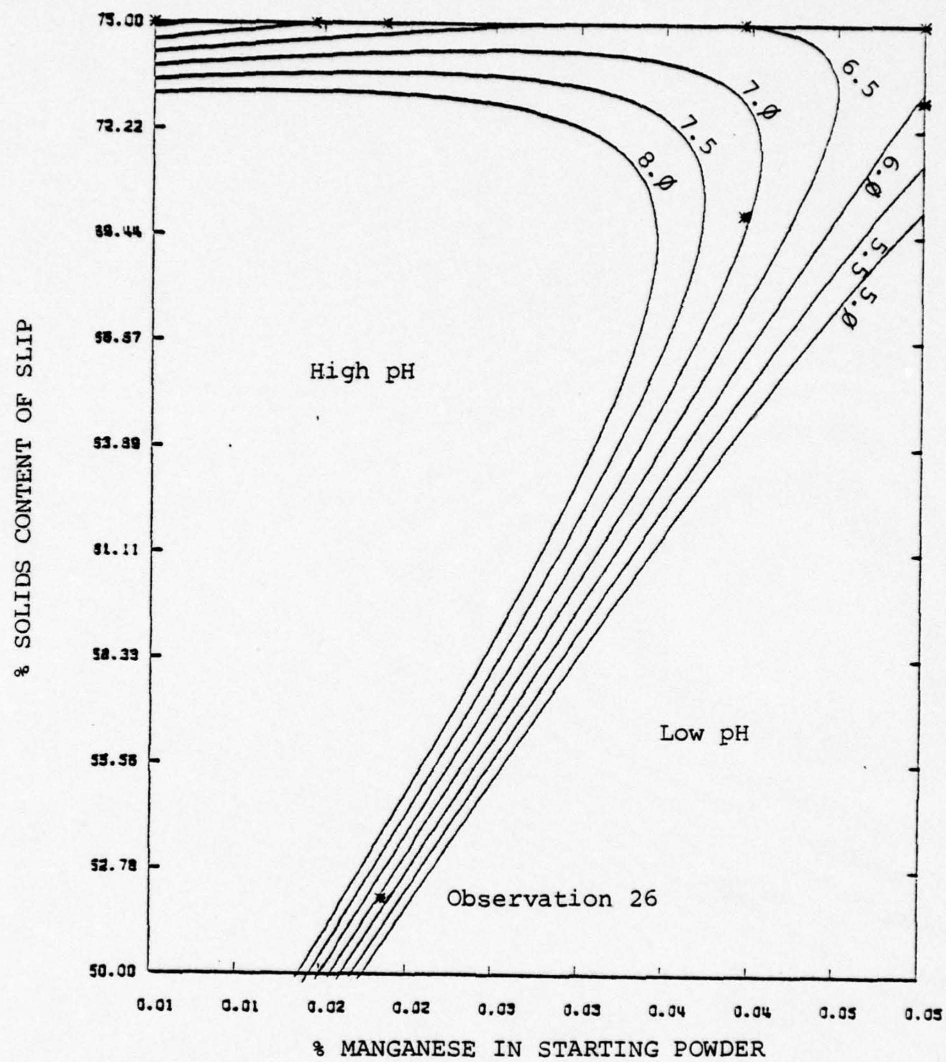
(R)	Range of the Data	: 2.2 (-)	Min = 4.9, Max = 5.9
(S)	Standard Deviation	: 0.545 (-)	
(e)	RMS Error on Training Data	: 0.19 (-)	
(E)	Expected Error on New Data	: 0.34 (-)	
(P)	Model Performance Measure (1-E/S)	: .37	

Partial Derivatives of Ph with Respect to the Model Input Variables:

% Manganese in Starting Powder (%)	:-69.66 (-/%)
Solids Content in Slip (%)	:- .21 (-/%)

FIGURE 3.6a: ALN MODEL PREDICTING SLIP pH AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT pH (-)



* - indicates location of training data

FIGURE 3.6b: CONTOURS OF pH PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

Media Qty. x_{59}

Defloc. x_{99}

Aging Time x_{103}

NH_4OH x_{102}

$$-.24 + .87x_{59} + .45x_{99} + .24x^2_{99} + .51x_{103} + .25x_{102}$$

$\rightarrow x_{130}$ Green Density

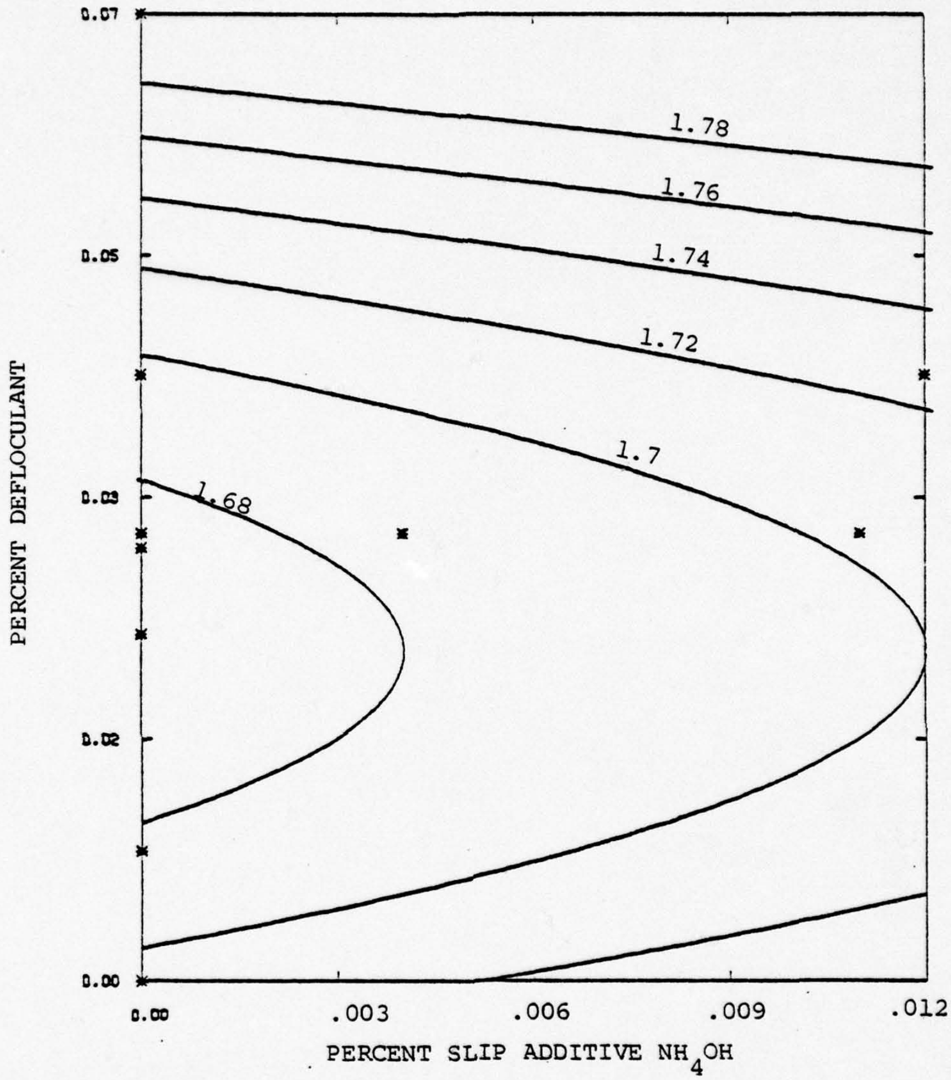
(R)	Range of the Data	:0.24 (gm/cm^3)	Min = 1.54 Max = 1.78
(S)	Standard Deviation	:0.05 (gm/cm^3)	
(e)	RMS Error on Training Data Base	:0.02 (gm/cm^3)	
(E)	Expected RMS Error on New Data	:0.03 (gm/cm^3)	
(P)	Model Performance Measure (1-E/S)	:0.40	

Partial Derivatives of Green Density with Respect to the Model Input Variables:

Additive NH_4OH (% Wght)	: 2.50	(gm/cm^3/%)
Deflocculant (% Wght)	: 2.25	(gm/cm^3/%)
Media Quantity (kg)	: 0.01	(gm/cm^3/Kg)
Slip Aging Time (Days)	: 0.003	(gm/cm^3/day)

FIGURE 3.7a: ALN MODEL PREDICTING GREEN DENSITY AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT GREEN DENSITY (GM/CM^3)



* - indicates location of training data

FIGURE 3.7b: CONTOURS OF GREEN DENSITY PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

Weight Gain: (Figure 3.8)

Weight gain increases proportionally to the particle size distribution ratio [(Weight Bin3 plus Weight Bin5) divided by Weight Bin4]. This ratio reflects the width of the PSD, indicating that a broad PSD yields high weight gain.

Increasing the percentage of iron in the starting powder tends to decrease the weight gain.

Decreasing the slip aging time appears to cause a minor increase in weight gain.

Nitrided Density: (Figure 3.9)

From the quadratic nature of the model, it appears that weight gain is relatively insensitive to the amount of deflocculant if the deflocculant is less than about 0.04% of the slip, but above 0.04%, additional deflocculant increases weight gain. But because of the very limited data above 0.03%, this conclusion must be considered to be very weak.

Decreasing the skewness, i.e., increasing the amount of small particle sizes, of the particle size distribution tends to increase the nitrided density.

Increasing the solids content of the slip appears to cause a minor increase in the nitrided density.

Alpha: (Figure 3.10)

Decreasing the amount of Fe_2O_3 additive in the slip decreases the proportion of Alpha-Silicon-Nitride in the final analysis.

Decreasing the amount of oxygen in the starting powder decreases the proportion of Alpha-Silicon Nitride.

Decreasing the slip temperature causes a minor decrease in the percentage of Alpha-Silicon-Nitride in the final analysis.

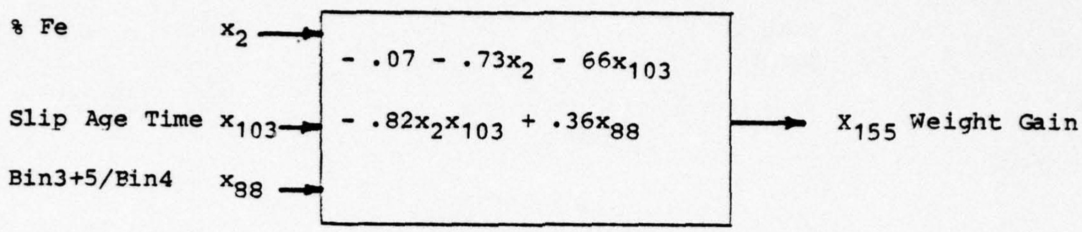
Beta: (Figure 3.11)

A lower percentage of Manganese in the starting powder results in a higher proportion of Beta-Silicon-Nitride in the final analysis.

Lower percentages of deflocculant in the slip preparation result in higher proportions of Beta-Silicon-Nitride.

Decreasing the 20th percentile size of the PSD (i.e., increasing the number of small particles) tends to increase slightly the proportion of Beta-Silicon-Nitride in the final product.

Decreasing the slip temperature has a minor tendency to increase the final percentage of Beta-Silicon-Nitride.



(R)	Range of the Data	: 7.7 (%) Min = 53.5, Max = 61.2
(S)	Standard Deviation	: 1.78 (%)
(e)	RMS Error on Training Data Base	: 0.89 (%)
(E)	Expected RMS Error on New Data	: 1.19 (%)
(P)	MOdel Performance Measure (1-E/S)	: 0.33

Partial Derivatives of % Weight Gain with Respect to the Model Input Variables

Ratio (Bin3 + Bin5)/Bin4	: 4.01 (%/%)
Fe in Starting Powder (%)	:-1.71 (%/%)
Slip Aging Time (days)	:-0.14 (%/day)

FIGURE 3.8a: ALN MODEL PREDICTING WEIGHT GAIN AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT WEIGHT GAIN (%)

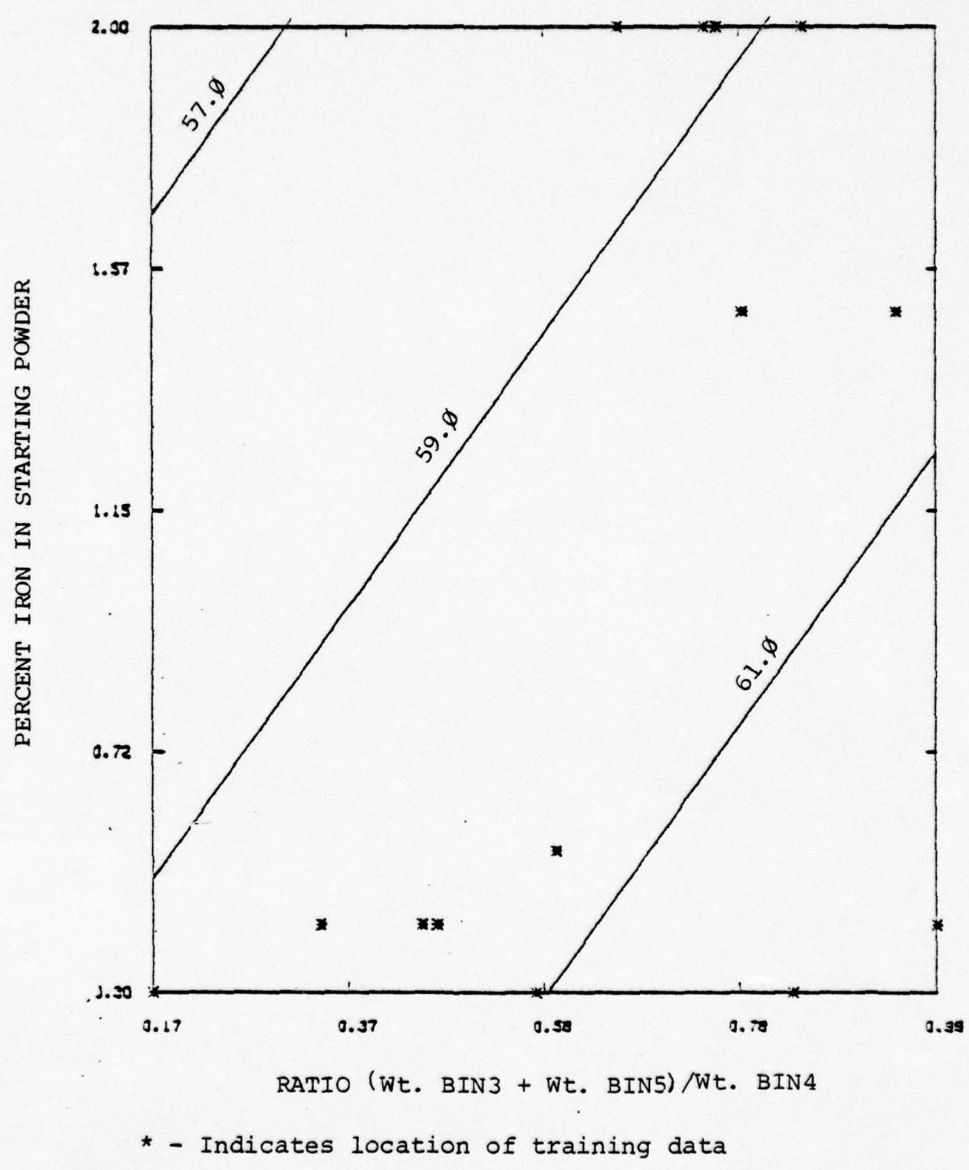


FIGURE 3.8b: CONTOURS OF WEIGHT GAIN PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

Solids Content x_{98} →

Deflocculant x_{99} →

Skewness x_{91} →

$$-.67 + 2.54x_{98} + .42\,x^2_{98} + .33x_{99} + .23x^2_{99} - .32x_{91}$$

→ x_{156}

Nitrided Density

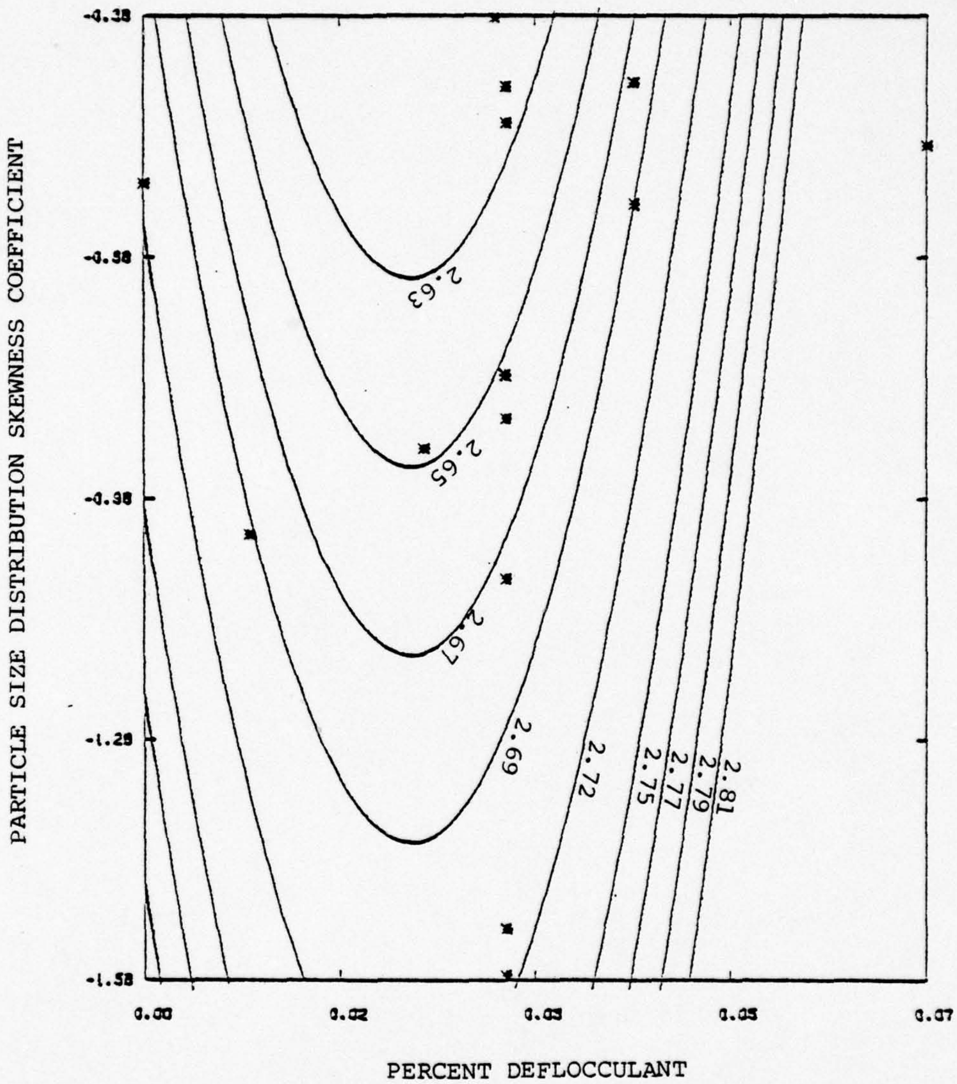
(R)	Range of the Data	: .33 (gm/cm^3) Min = 68.4, Max = 89.3
(S)	Standard Deviation	: .08 (gm/cm^3)
(e)	RMS Error on Training Data Base	: .03 (gm/cm^3)
(E)	Expected RMS Error on New Data	: .05 (gm/cm^3)
(P)	Model Performance Measure (1-E/S)	: .37

Partial Derivatives of Nitrided Density with Respect to the Model Input Variables

Deflocculant (% of Wght)	: 2.64 (gm/cm^3/%)
Coefficient of Skewness	: -0.09 (gm/cm^3/-)
Solids Content (% of Weight)	: 0.05 (gm/cm^3/%)

FIGURE 3.9a: ALN MODEL PREDICTING NITRIDED DENSITY AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT NITRIDED DENSITY (GM/CM^3)



* - Indicates location of training data

FIGURE 3.9b: CONTOURS OF NITRIDED DENSITY PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

$\%O_2$ x_{10} →
Fe_2O_3 x_{101} →
Slip Temp. x_{104} →

$$.46x_{10} + .62x_{101} + .28x_{104}$$

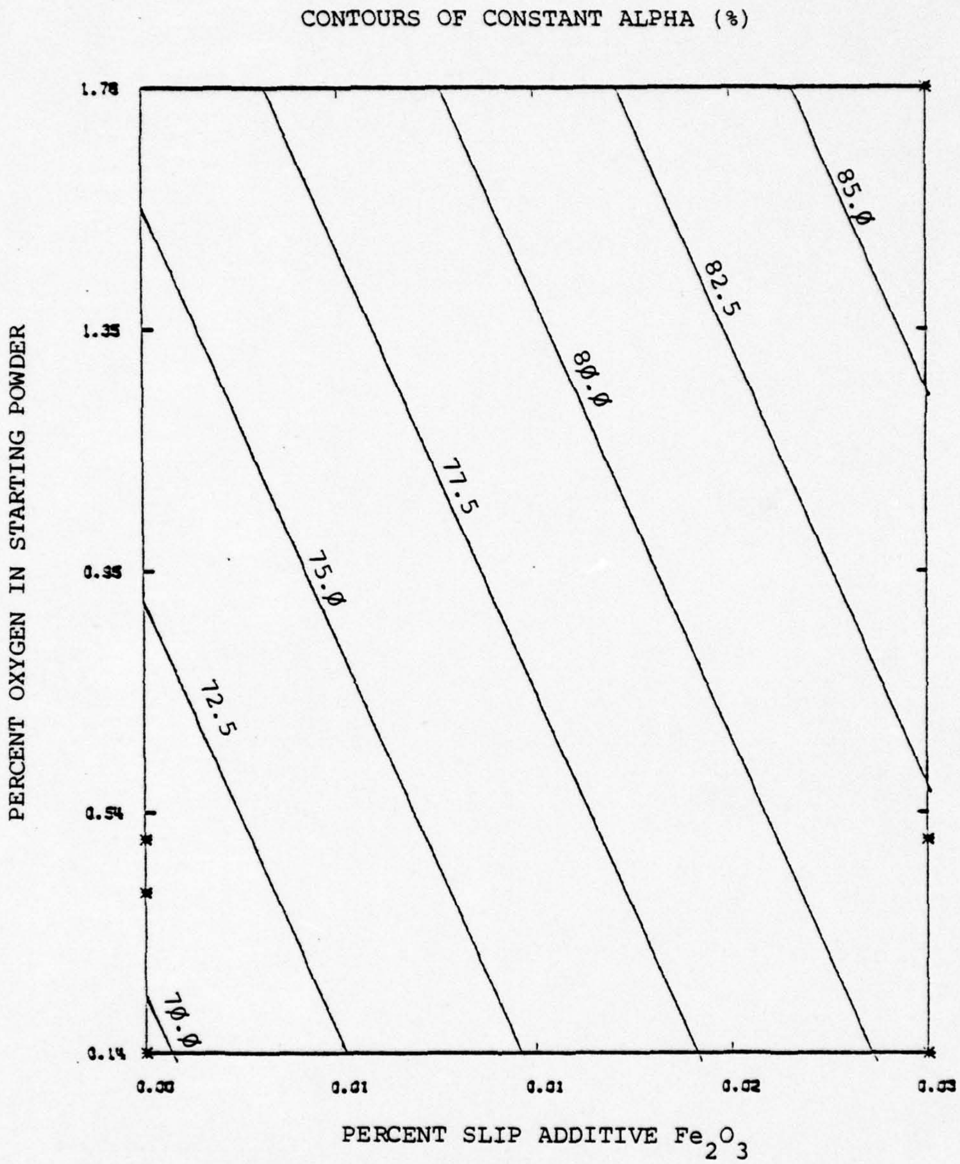
→ x_{157} Alpha

(R)	Range of the Data	: 20.9	(Rel. %)	Min = 68.4 Max = 89.3
(S)	Standard Deviation	: 6.0	(Rel. %)	
(e)	RMS Error on Training Data Bases	: 3.0	(Rel. %)	
(E)	Expected Error on New Data	: 3.80	(Rel. %)	
(P)	Model Performance Measure (1-E/S)	: 0.37		

Partial Derivatives of Alpha with Respect to the Model Input Variables:

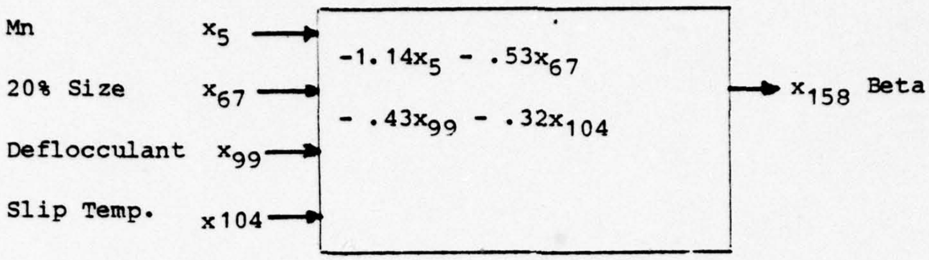
Slip Additive Fe_2O_3 (%)	: 3.72.Ø	(%/%)
Oxygen Content in Starting Pwdr.(%)	: 3.78	(%/%)
Slip Temperature (°F)	: 0.84	(%/%)

FIGURE 3.10a: ALN MODEL PREDICTING ALPHA AS A FUNCTION OF INDEPENDENT VARIABLES



* - Indicates location of training data

FIGURE 3.10b: CONTOURS OF ALPHA-SILICON-NITRIDE PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

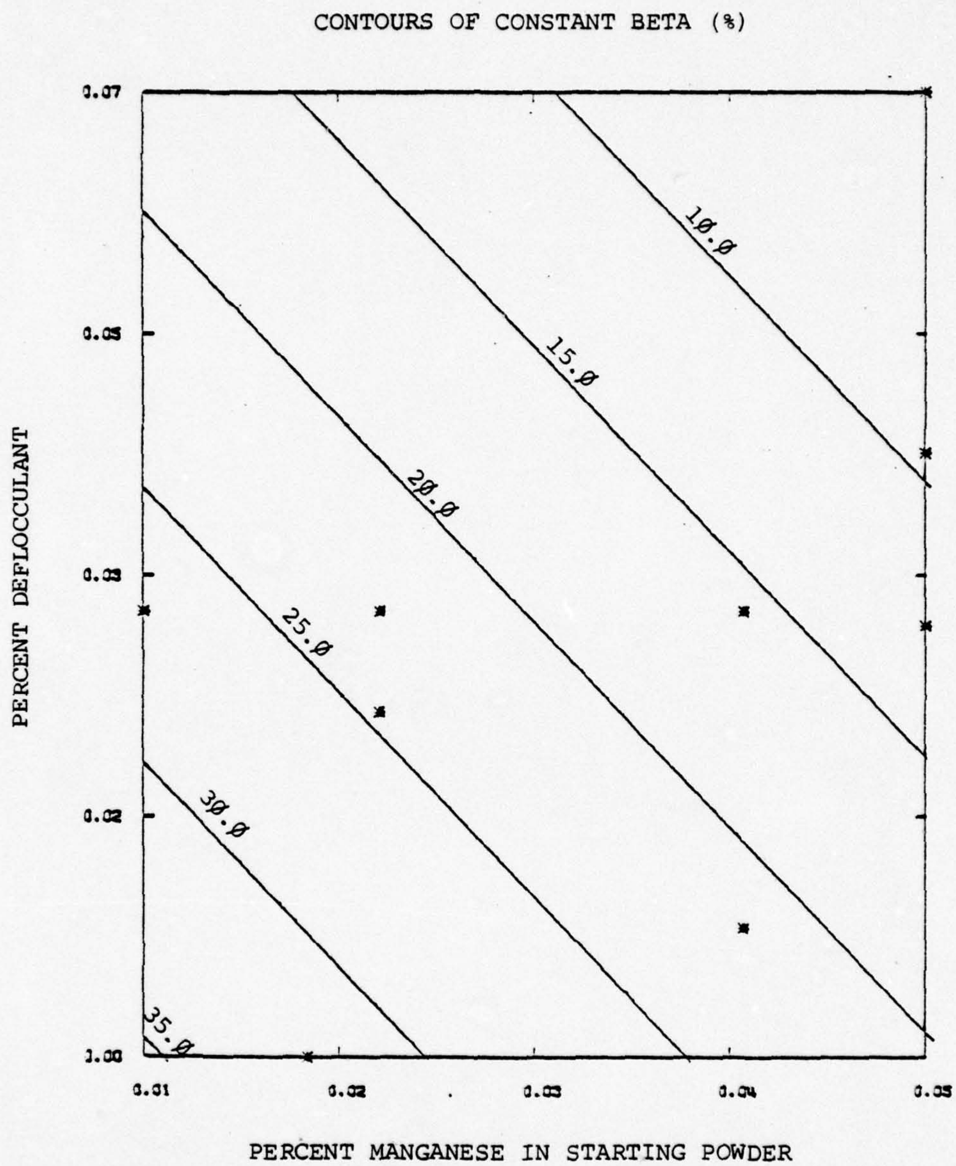


(R)	Range of the Data	: 21.4	(Rel. %) Min = 7.8, Max = 29.2
(S)	Standard Deviation	: 6.1	(Rel. %)
(e)	RMS Error on Training Data Base	: 2.78	(Rel. %)
(E)	Expected Error on New Data	: 3.91	(Rel. %)
(P)	Model Performance Measure (1-E/S)	: 0.36	

Partial Derivatives of Beta with Respect to the Model Input Variables:

% Manganese in Starting Powder	: -347.7	(%/%)
Deflocculant (% of Weight)	: -262.3	(%/%)
20 Percentile Size (Log)	: - 1.39	(%/-)
Slip Temperature (°F)	: - 0.98	(%/°F)

FIGURE 3.11a: ALN MODEL PREDICTING BETA AS A FUNCTION OF INDEPENDENT VARIABLES



* - Indicates location of training data

FIGURE 3.11b: CONTOURS OF PERCENT BETA-SILICON-NITRIDE PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

Silicon-Oxy-Nitride (Si_2ON_2): (Figure 3.12)

Titanium in the starting powder increases the percentage of silicon-oxy-nitride in final material.

Adding Fe_2O_3, however, appears to reduce slightly the amount of silicon-oxy-nitride.

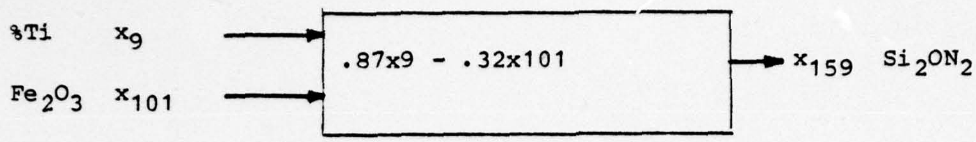
3.3 SUMMARY OF KEY EFFECTS

The key hypotheses obtained from the networks are diagrammed in Figures 3.13a and b. High average strength results primarily from high weight gain and high nitrided density, which in turn are achieved with a broad, unimodal particle size distribution with with a small mean size and with low iron in the starting powder. Low alpha-silicon-nitride also improves strength and is achieved by minimizing oxygen in the starting powder and by using smaller amounts of ferris oxide additive in the slip preparation.

Low strength variance, i.e., high Weibull modulus, is achieved by minimizing silicon-oxy-nitride and to a lesser extent by using smaller particle sizes. The silicon-oxy-nitride appears to be increased most by titanium in the starting powder.

Production conditions yielding high average strengths also yield fairly consistent strengths, i.e., high Weibul modulus, while low average strengths are generally accompanied by large variation in part strengths.

Within the range of the 35 data observations used in this analysis, it does not appear that slip pH, green density, or sintering parameters have a significant impact on strength or strength variance. Though nitriding parameters, such as temperatures, times or nitrogen pressures, were not selected by the networks, it must be pointed out that there was not significant variation of those parameters in the data base. Further data should be collected to determine the affects of nitriding on strength and strength variance.



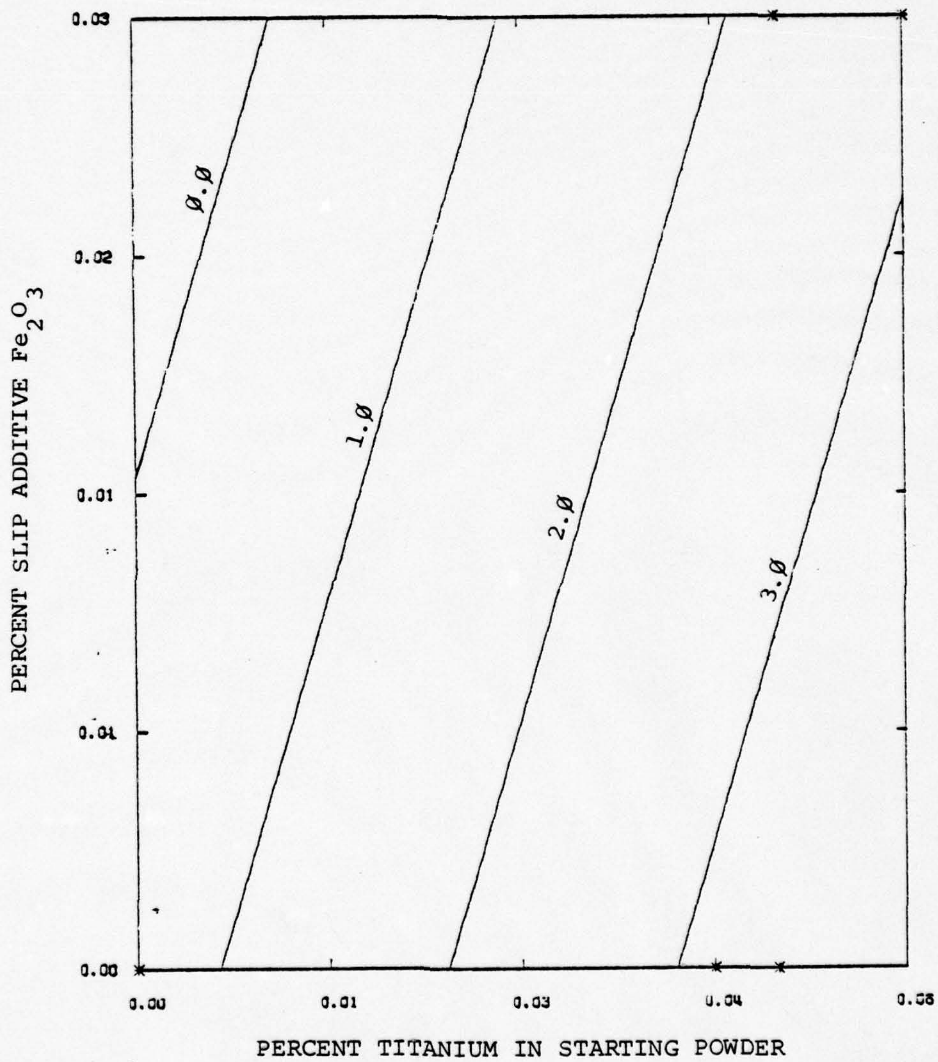
(R)	Range of the Data	: 5.5 (%) Min = 0.0, Max = 5.5
(S)	Standard Deviation	: 1.29 (%)
(e)	RMS Error on Training Data Base	: 1.0 (%)
(E)	Expected RMS Error on New Data	: 1.06 (%)
(P)	Model Performance Measure C1-E/S)	: 0.18

Partial Derivatives OF % Si_2ON_2 with Respect to the Model Input Variables

% Titanium in Starting Powder	: 56.12 (%/%)
% Slip Additive (Fe_2O_3)	: -41.28 (%/%)

FIGURE 3.12a: ALN MODEL PREDICTING % Si_2ON_2 AS A FUNCTION OF INDEPENDENT VARIABLES

CONTOURS OF CONSTANT Si_2ON_2



* - Indicates location of training data

FIGURE 3.12b: CONTOURS OF PERCENT Si_2ON_2 PLOTTED AS A FUNCTION OF INDEPENDENT VARIABLES

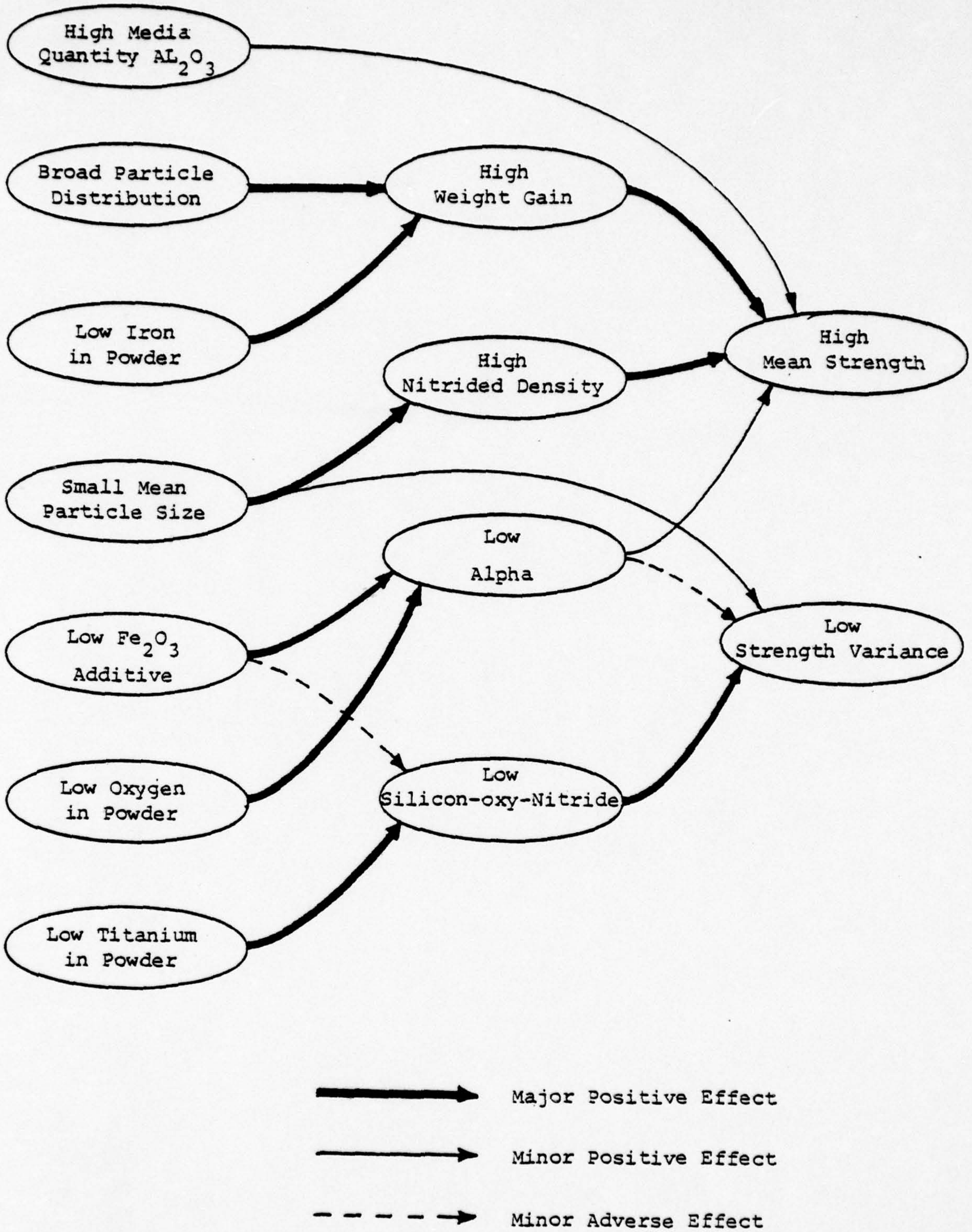


FIGURE 3.13a: FLOW CHART OF PREDOMINANT SLIP CAST RBSN PROCESS EFFECTS

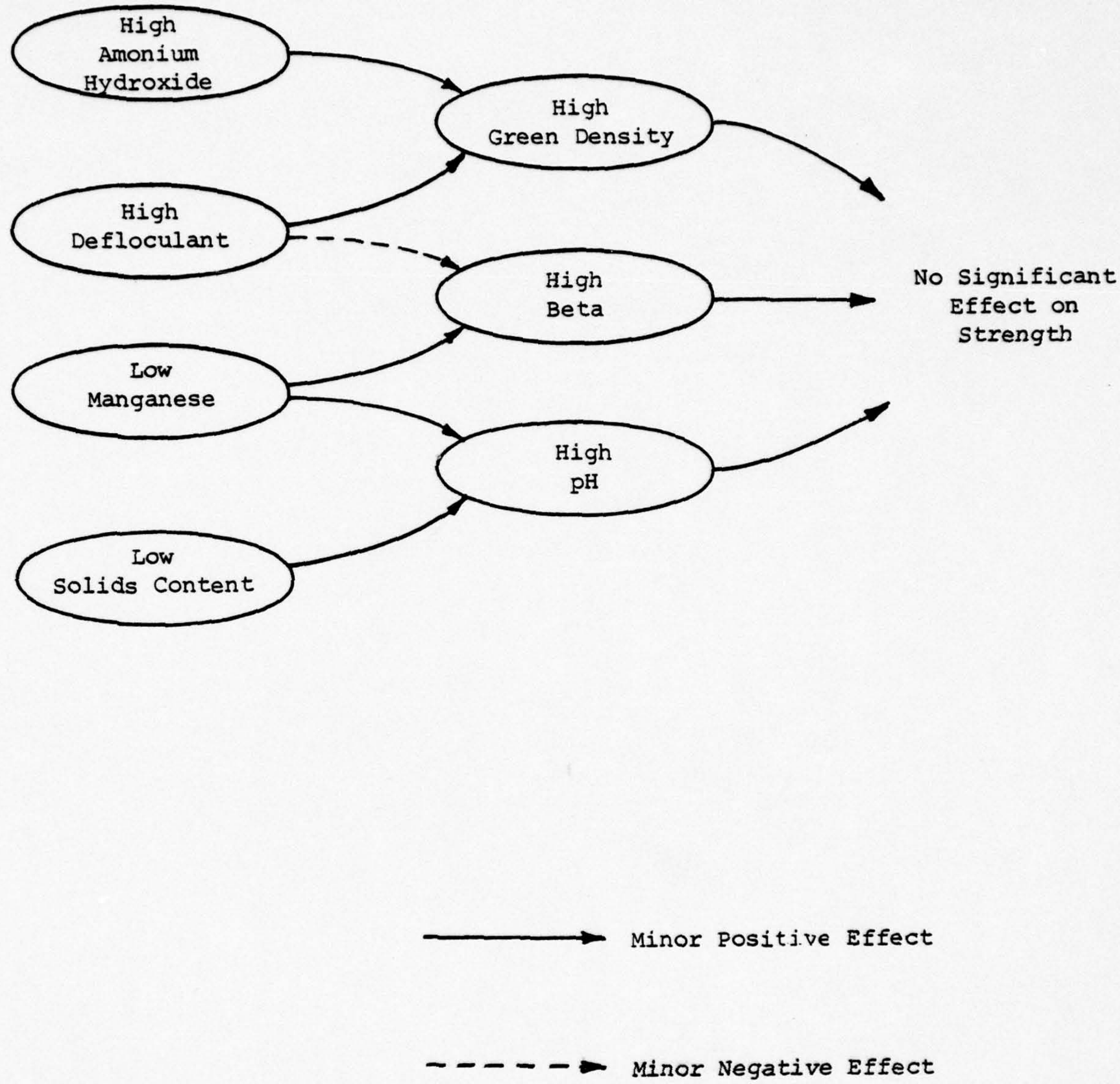


FIGURE 3.13b: FLOW CHART OF PREDOMINANT SLIP CAST RBSN PROCESS EFFECTS

4. CONCLUSIONS AND RECOMMENDATIONS

The Adaptive Learning Network methodology has been demonstrated to be a powerful tool for the analysis of a slip-cast, reaction-bonded, silicon-nitride manufacturing process. Though the data is limited (only 35 manufacturing variations were available), many trends have been identified which will be useful in guiding a continued search for the optimum manufacturing conditions.

The models developed to date do not exhibit clear cut peaks showing optimum values parameter settings; rather, they show trends which suggest that further variations of the parameters will yield improved material properties. It appears that strengths well above 48 ksi (the strongest achieved to date) are possible.

There was little variation of the nitriding parameters in the given data base, so the impacts of nitriding on material strength could not be estimated. In future work it is recommended that data be collected for a wide range of nitriding conditions.

It is also recommended that future work address high temperature strengths as well as room temperature strengths, so that strengths may be optimized for the operational environment of the RBSN materials

5. REFERENCES

1. Ceramic Components for Turbine Engines, Fifth and Sixth Interim (Quarterly) Technical Reports, AiResearch Manufacturing Company, Contract F33615-77-C-5171, AFML Wright-Patterson AFB, June and September 1979.

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APPENDIX 1

SLIP-CAST REACTION-BONDED SILICON-NITRIDE DATA BASE

Notes:

(1) The data base is in two parts. Section 1 presents the following statistics for each variable in the data base: mean, standard deviation, range, minimum value, and maximum value. Section 2 presents the 35 individual values of each variable.

(2) In Section 2, an asterisk next to a zero entry indicates that no measurement was made for that entry.

(3) Particle size data is given in the following log form:

s = size in micrometers
x = log size
$x = 10 \log (10s)$

$$s = 10^{\frac{x-10}{10}}$$

SECTION 1: VARIABLE STATISTICS

SUBPROCESS A
STARTING POWDER

Parameter Number and Name	Mean Value	Standard Deviation	Range	Min.	Max.
1 CALCIUM PERCENTAGE	.0249	.0105	.0300	.0000	.0300
2 IRON PERCENTAGE	1.3951	.7609	1.5800	.4200	2.0000
3 ALUMINUM PERCENTAGE	.2051	.1193	.2000	.0000	.2000
4 MAGNESIUM PERCENTAGE	.0053	.0021	.0050	.0020	.0070
5 MANGANESE PERCENTAGE	.0373	.0164	.0430	.0070	.0500
6 CARBON PERCENTAGE	.0149	.0414	.0000	.0000	.0000
7 POTASSIUM PERCENTAGE	.0114	.0318	.0000	.0000	.0000
8 OXYGEN PERCENTAGE	.2846	.1946	.4300	.0000	.4300
9 TITANIUM PERCENTAGE	.0507	.0188	.0600	.0000	.0600
10 OXYGEN ANALYSIS (PRCNT)	1.1377	.7262	1.3500	.4100	1.7600
11 OXYGEN ANALYSIS +/- PRCNT	.7354	.3148	.2500	.7000	.9500
12 AVG PART SIZE (MICM)	9.6171	10.3722	3.8000	3.2000	7.0000
13 MAX PART SIZE LENGTH	223.5714	68.8535	155.0000	120.0000	275.0000
14 MAX PART SIZE WIDTH	194.4286	71.7511	200.0000	50.0000	250.0000
15 SURFACE AREA (M2/GM)	3.7286	2.5290	4.5000	1.4000	5.9000
16 20 PRCNTILE SIZE (LOG)	12.7389	6.1626	12.6622	.0000	12.6622
17 50 PRCNTILE SIZE (LOG)	15.1637	7.2290	15.0357	.0000	15.0357
18 80 PRCNTILE SIZE (LOG)	17.2880	7.7601	17.8795	.0000	17.8795
19 95 PRCNTILE SIZE (LOG)	19.4059	8.3459	20.8235	.0000	20.8235
20 98 PRCNTILE SIZE (LOG)	21.2549	8.8542	23.6667	.0000	23.6667
21 MAX PART SIZE (LOG)	28.4571	11.6750	34.0000	.0000	34.0000
22 PRCNT .GT.40 MICROMETERS	5.3143	8.7524	1.2000	.0000	1.2000
23 PRCNT .GT.20 MICROMETERS	15.7114	27.1721	2.2000	.0000	2.2000
24 PRCNT .GT.10 MICROMETERS	24.8342	31.6483	7.8000	.0000	7.8000
25 PRCNT .GT. 5 MICROMETERS	57.4602	29.3924	54.0190	.0000	54.0190
26 PRCNT .GT. 1 MICROMETERS	81.6370	33.4327	93.3000	.0000	93.3000
27 WGHT BIN1 .0-S-.3	.1461	.1257	.2540	.0000	.2540
28 WGHT BIN2 .3-S-1.	3.9320	3.0006	6.4460	.0000	6.4460
29 WGHT BIN3 1.-S-3.	24.1768	18.0128	39.2810	.0000	39.2810
30 WGHT BIN4 3.-S-10.	32.6260	18.3052	46.2190	.0000	46.2190
31 WGHT BIN5 10.-S-30.	14.0640	14.6299	6.1310	.0000	6.1310
32 WGHT BIN6 30.-S-...	10.7702	18.8483	1.6690	.0000	1.6690
33 RATIO BIN2/BIN4	.0858	.0647	.1395	.0000	.1395
34 RATIO BIN3/BIN4	.5383	.3748	.8499	.0000	.8499
35 RATIO BIN5/BIN4	.6939	1.0276	.1327	.0000	.1327
36 RATIO BIN2+3/BIN4	.6242	.4394	.9894	.0000	.9894
37 RATIO BIN3+5/BIN4	1.2321	.8538	.9825	.0000	.9825
38 FIRST MOMENT OF LOG PSD	14.5748	6.7981	14.7192	.0000	14.7192
39 STAND. DEV. OF LOG PSD	3.0257	1.2496	3.5979	.0000	3.5979
40 COEF. OF SKEWNESS LOG PSD	-.0211	.5884	.4148	.0000	.4148
41 KURTOSIS OF LOG PSD	3.7399	1.6703	4.8631	.0000	4.8631
42 RATIO STD DEV/MEAN	.1059	.0864	.2444	.0000	.2444
43 RMS DEV FROM FITTED PSD	-.0145	.0151	.0089	-.0089	.0000
44 FITTED PSD PEAK(MICM) (A)	14.1543	6.2129	14.7700	.0000	14.7700
45 FITTED PSD RISE COEF. (B)	2.7009	1.8234	4.2600	.0000	4.2600
46 FITTED PSD FALL COEF. (C)	.6609	.7996	.5000	.0000	.5000

SUBPROCESS B
POWDER PREPARATION

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
47 CALCIUM PERCENTAGE	.0094	.0139	.0300	.0000	.0300
48 IRON PERCENTAGE	1.5714	2.3212	5.0000	.0000	5.0000
49 ALUMINUM PERCENTAGE	.0629	.0928	.2000	.0000	.2000
50 MAGNESIUM PERCENTAGE	.0016	.0023	.0050	.0000	.0050
51 MANGANESE PERCENTAGE	.0157	.0232	.0500	.0000	.0500
52 TITANIUM PERCENTAGE	.0189	.0279	.0600	.0000	.0600
53 VANADIUM PERCENTAGE	.0314	.0464	.1000	.0000	.1000
54 OXYGEN ANALYSIS (PRCNT)	1.8834	2.6191	2.9700	.0000	2.9700
55 OXYGEN ANALYSIS +/- PRCNT	.7389	.9606	1.1750	.0000	1.1750
56 BALL MILL TIME (HRS)	14.6286	4.4791	.0000	16.0000	16.0000
57 VIBRATION MILL TIME (HRS)	.2286	.9285	.0000	.0000	.0000
58 AIR CLASSIFY (YES/NO)	.1714	.3769	.0000	.0000	.0000
59 MEDIA QUANTITY (AL2O3,KG)	10.0531	3.4868	3.7600	10.1000	13.8600
60 ADDITIVES FE2O3	.0291	.0050	.0300	.0000	.0300
61 ADDITIVES BORON	.1316	.2544	.0000	.0000	.0000
62 AVG PART SIZE (MICM)	3.7857	1.2889	1.5000	3.1000	4.6000
63 MAX PART SIZE LENGTH	161.0286	111.8230	253.0000	22.0000	275.0000
64 MAX PART SIZE WIDTH	147.6000	101.0530	228.0000	22.0000	250.0000
65 SURFACE AREA (M2/GM)	5.7286	2.3139	2.2000	4.3000	6.5000
66 STORAGE TIME (HOURS)	.0000	.0000	.0000	.0000	.0000
67 20 PRCNTILE SIZE (LOG)	11.8049	2.3292	6.0633	10.0870	16.1503
68 50 PRCNTILE SIZE (LOG)	15.9061	1.3019	3.0051	14.8667	17.8718
69 80 PRCNTILE SIZE (LOG)	18.6609	1.1536	2.4199	17.7468	20.1667
70 95 PRCNTILE SIZE (LOG)	21.0346	1.0318	2.1320	20.1923	22.3243
71 98 PRCNTILE SIZE (LOG)	22.2890	.9929	1.7708	21.5626	23.3333
72 MAX PART SIZE (LOG)	30.5143	4.0694	9.0000	25.0000	34.0000
73 PRCNT .GT.40 MICROMETERS	.2743	.2622	.4000	.0000	.4000
74 PRCNT .GT.20 MICROMETERS	1.5829	1.4966	1.7000	.8000	2.5000
75 PRCNT .GT.10 MICROMETERS	11.4143	7.5051	16.0000	5.5000	21.5000
76 PRCNT .GT. 5 MICROMETERS	62.2941	14.2123	37.6370	51.1600	88.7970
77 PRCNT .GT. 1 MICROMETERS	85.1771	6.8417	17.5000	80.2000	97.7000
78 WGHT BIN1 .0-S-.3	2.5366	1.1853	2.6090	.3850	2.9940
79 WGHT BIN2 .3-S-1.	12.2862	5.8318	14.8910	1.9150	16.8060
80 WGHT BIN3 1.-S-3.	22.8828	7.6357	20.1370	8.9030	29.0400
81 WGHT BIN4 3.-S-10.	50.8799	9.6071	21.6370	45.6600	67.2970
82 WGHT BIN5 10.-S-30.	10.9087	7.3803	16.2930	4.9770	21.2700
83 WGHT BIN6 30.-S-...	.5056	.5066	.2930	.2300	.5230
84 RATIO BIN2/BIN4	.2645	.1430	.3396	.0285	.3681
85 RATIO BIN3/BIN4	.4830	.2007	.5037	.1323	.6360
86 RATIO BIN5/BIN4	.2100	.1401	.2071	.1090	.3161
87 RATIO BIN2+3/BIN4	.7474	.3403	.8433	.1608	1.0041
88 RATIO BIN3+5/BIN4	.6929	.1627	.2966	.4484	.7450
89 FIRST MOMENT OF LOG PSD	14.7181	1.4384	3.7285	13.5735	17.3020
90 STAND. DEV. OF LOG PSD	4.2753	.6148	1.4721	3.0484	4.5205
91 COEF. OF SKEWNESS LOG PSD	-.6711	.3011	.6167	-1.0801	-.4634
92 KURTOSIS OF LOG PSD	3.5779	.9544	3.0963	3.0143	6.1106
93 RATIO STD DEV/MEAN	.2957	.0589	.1568	.1762	.3330
94 RMS DEV FROM FITTED PSD	.0105	.0028	.0015	.0115	.0130
95 FITTED PSD PEAK(MICM) (A)	16.4920	1.1410	2.0300	15.6600	17.6900
96 FITTED PSD RISE COEF. (B)	1.9869	1.3571	3.9100	1.0900	5.0000
97 FITTED PSD FALL COEF. (C)	1.3626	.6775	.8300	.6700	1.5000

SUBPROCESS D
SLIP PREPARATION

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
98 SOLIDS CNTNT(WGHT PRCNT)	73.5429	3.9304	.0000	75.0000	76.0000
99 DEFLOCULANT (WGHT. PRCNT)	.0350	.0128	.0110	.0310	.0420
100 ADDITIVE ACID (WGHT. PRCNT)	.0011	.0025	.0000	.0000	.0000
101 ADDITIVE FE2O3 (WGHT. PRCNT)	.0249	.0113	.0300	.0000	.0300
102 ADDITIVE NH4OH (WGHT. PRCNT)	.0031	.0051	.0000	.0000	.0000
103 AGING TIME (DAYS)	12.7143	8.3000	8.0000	13.0000	21.0000
104 TEMPERATURE (DEG. F)	70.5143	1.9910	4.0000	69.0000	73.0000
105 PH	5.7314	.5450	1.0000	4.9000	5.9000
106 VISCOSITY 1/60 (CPS)	84.7000	30.3372	.0000	100.0000	100.0000
107 VISCOSITY 1/30 (CPS)	112.3143	46.7673	33.0000	100.0000	133.0000
108 VISCOSITY 1/12 (CPS)	176.7714	84.0192	183.0000	192.0000	375.0000
109 THIXOTROPIC INDEX	1.9974	.4336	1.9600	1.7600	3.7000

SUBPROCESS F

SINTERING

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
110 SINTERING TIME (HOURS)	5.8286	3.3593	.0000	4.0000	4.0000
111 TEMPERATURE (DEG. C)	1086.2860	25.1947	.0000	1100.0000	1100.0000
112 VACUUM (MICRO)	49.4571	57.8990	55.0000	70.0000	125.0000
113 TIME .GT. 200 DEG C HRS	25.0571	5.0200	10.2500	20.0000	30.2500
114 TIME .GT. 400 DEG C HRS	20.4786	2.9071	[illegible].2500	18.7500	23.0000
115 TIME .GT. 600 DEG C HRS	15.9357	1.8150	1.2500	16.0000	17.2500
116 TIME .GT. 800 DEG C HRS	10.9867	2.3792	5.5000	9.0000	14.5000
117 TIME .GT. 900 DEG C HRS	9.0429	2.4005	5.5000	7.2500	12.7500
118 TIME .GT. 1000 DEG C HRS	7.4786	2.8694	6.5000	5.5000	12.0000
119 DEG HRS .GT. 200 DEG C	13226.0500	1385.5080	122.6445	13675.4500	13798.1000
120 DEG HRS .GT. 400 DEG C	8660.0120	1068.1850	1574.4370	8340.5470	9914.9840
121 DEG HRS .GT. 600 DEG C	5007.1910	879.9263	1872.3750	4424.0590	6296.4340
122 DEG HRS .GT. 800 DEG C	2308.4160	508.3044	1167.5930	1923.7080	3091.3010
123 DEG HRS .GT. 900 DEG C	1309.5990	267.1816	612.1589	1113.2090	1725.3680
124 DEG HRS .GT. 1000 DEG C	485.1411	19.2607	9.1648	470.8352	480.0000
125 TIME 21-900 DEG C (HRS)	16.3786	9.1121	21.5000	4.2500	25.7500
126 TIME 900-21 DEG C (HRS)	3.9143	.3962	.7500	3.7500	4.5000
127 OXYGEN ANALYSIS (PRCNT)	.0931	.3786	1.6900	.0000	1.6900
128 OXYGEN ANALYSIS +/- PRCNT	.0226	.0917	.4000	.0000	.4000
129 PERMEABILITY	.0000	.0000	.0000	.0000	.0000
130 GREEN DENSITY (GM/CM3)	1.7011	.0490	.0000	1.7200	1.7200
131 PERCENT WEIGHT LOSS	.5029	.5372	1.9000	.0000	1.9000

SUBPROCESS G

NITRIDING

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
132 FURNACE LOAD (GMS)	3372.Ø57Ø	291.3684	111Ø.ØØØØ	335Ø.ØØØØ	446Ø.ØØØØ
133 VACUUM LEVEL (MICRO)	95.4286	38.4219	1ØØ.ØØØØ	1ØØ.ØØØØ	2ØØ.ØØØØ
134 LEAK-UP RATE	9.7714	.6363	.ØØØØ	1Ø.ØØØØ	1Ø.ØØØØ
135 HOURS PRIOR N2 FLOW	5.3714	1.3853	4.ØØØØ	2.ØØØØ	6.ØØØØ
136 ATMOSPHERE PRCNT N2	.96ØØ	.ØØØØ	.ØØØØ	.96ØØ	.96ØØ
137 ATMOSPHERE PRCNT H2	.Ø4ØØ	.ØØØØ	.ØØØØ	.Ø4ØØ	.Ø4ØØ
138 NITRID. TIME (DAYS)	17.6857	2.896Ø	7.ØØØØ	12.ØØØØ	19.ØØØØ
139 PEAK TEMP (DEG. C)	1397.257Ø	9.7111	1Ø.ØØØØ	14ØØ.ØØØØ	141Ø.ØØØØ
14Ø SHIELDING Ø=NO,1=YES	.4ØØØ	.4899	1.ØØØØ	.ØØØØ	1.ØØØØ
141 TIME .GT 4ØØ DEG C DAYS	19.5118	3.73Ø2	9.6666	11.5417	21.2Ø83
142 TIME .GT 6ØØ DEG C DAYS	19.4359	3.7368	9.6562	11.4792	21.1354
143 TIME .GT 8ØØ DEG C DAYS	19.3354	3.7292	9.6146	11.4167	21.Ø313
144 TIME .GT 1ØØØ DEG C DAYS	18.9958	3.7693	9.3645	11.3438	2Ø.7Ø83
145 TIME .GT 11ØØ DEG C DAYS	8.895Ø	.4438	.3229	9.Ø313	9.3542
146 TIME .GT 12ØØ DEG C DAYS	5.9366	.4265	.9167	6.Ø1Ø4	6.9271
147 TIME .GT 13ØØ DEG C DAYS	2.8964	.4785	.8333	3.ØØØØ	3.8333
148 DEG DAYS .GT. 4ØØ DEG C	14216.5ØØØ	2437.941Ø	5827.559Ø	9494.793Ø	15322.35ØØ
149 DEG DAYS .GT. 6ØØ DEG C	1Ø321.93ØØ	1692.813Ø	3895.762Ø	7192.376Ø	11Ø88.14ØØ
15Ø DEG DAYS .GT. 8ØØ DEG C	6444.973Ø	95Ø.3Ø13	1968.137Ø	49Ø3.5Ø8Ø	6871.645Ø
151 DEG DAYS .GT. 1ØØØ DEG C	26Ø2.143Ø	239.Ø866	64.1199	2627.881Ø	2692.ØØ1Ø
152 DEG DAYS .GT. 11ØØ DEG C	1328.371Ø	117.8926	223.5337	1352.Ø14Ø	1575.548Ø
153 DEG DAYS .GT. 12ØØ DEG C	586.9573	75.7266	161.1487	6ØØ.2432	761.3918
154 DEG DAYS .GT. 13ØØ DEG C	143.1379	32.31Ø9	61.6Ø78	149.5817	211.1895
155 WEIGHT GAIN PRCNT	57.6771	1.785Ø	3.3ØØØ	55.8ØØØ	59.1ØØØ
156 NITRIDED DENSITY (GM/CM3)	2.6886	.Ø8Ø8	.Ø6ØØ	2.7ØØØ	2.76ØØ

FINAL ANALYSIS

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
157 ALPHA (X-RAY REL. PRCNT)	80.8513	6.0065	11.0000	71.9000	82.9000
158 BETA (X-RAY REL. PRCNT)	16.0800	6.0772	11.3000	11.6000	22.9000
159 SI2ON2 (X-RAY REL. PRCNT)	2.6200	1.2865	5.5000	.0000	5.5000
160 SI (X-RAY REL. PRCNT)	.2200	.6400	1.6000	.0000	1.6000
161 RATIO ALPHA/BETA	5.9416	2.5544	4.0069	3.1397	7.1466
162 RATIO BETA/ALPHA	.2057	.0940	.1786	.1399	.3185
163 RATIO SI2ON2/ALPHA	.0320	.0156	.0663	.0000	.0663
164 RATIO SI2ON2/BETA	.2039	.1388	.4741	.0000	.4741
165 PORE SIZE DIST.	.0000	.0000	.0000	.0000	.0000

STRENGTH DATA

Parameter Number and Name	Mean	Standard Deviation	Range	Min.	Max.
166 MOR MAXIMUM VALUE (KSI)	38.3799	8.3307	21.4000	27.1000	48.5000
167 MOR MINIMUM VALUE (KSI)	23.3086	7.9338	25.4000	14.4000	39.8000
168 MOR MEAN VALUE (KSI)	32.3213	7.8244	21.1600	23.1400	44.3000
169 MOR STAND. DEVIATION	4.9383	2.1916	.6800	3.1200	3.8000
170 WEIBULL CHARACTERISTIC	34.3078	8.0539	20.9930	24.7070	45.7000
171 WEIBULL SLOPE (SHAPE)	8.8201	3.5406	10.3750	7.1760	17.5500
172 CORRELATION COEF.	.9619	.0269	.0360	.9560	.9920

SECTION 2: VARIABLE VALUES

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS A STARTING POWDER

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
PARAMETER NUMBER AND NAME										
1 CALCIUM PERCENTAGE	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
2 IRON PERCENTAGE	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
3 ALUMINUM PERCENTAGE	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200
4 MAGNESIUM PERCENTAGE	.007	.007	.007	.007	.007	.007	.007	.007	.007	.007
5 MANGANESE PERCENTAGE	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
6 CARBON PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
7 POTASSIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
8 OXYGEN PERCENTAGE	.430	.430	.430	.430	.430	.430	.430	.430	.430	.430
9 TITANIUM PERCENTAGE	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060
10 OXYGEN ANALYSIS (PRCNT)	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760
11 OXYGEN ANALYSIS +/- PRCNT	.950	.950	.950	.950	.950	.950	.950	.950	.950	.950
12 AVG PART SIZE (MICM)	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200
13 MAX PART SIZE LENGTH	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000
14 MAX PART SIZE WIDTH	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000
15 SURFACE AREA (M2/GM)	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900
16 20 PRCNTILE SIZE (LOG)	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662
17 50 PRCNTILE SIZE (LOG)	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036
18 80 PRCNTILE SIZE (LOG)	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880
19 95 PRCNTILE SIZE (LOG)	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824
20 98 PRCNTILE SIZE (LOG)	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667
21 MAX PART SIZE (LOG)	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000
22 PRCNT .GT.40 MICROMETERS	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
23 PRCNT .GT.20 MICROMETERS	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200
24 PRCNT .GT.10 MICROMETERS	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800
25 PRCNT .GT. 5 MICROMETERS	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019
26 PRCNT .GT. 1 MICROMETERS	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300
27 WGHT BIN1 .0-S-.3	.254	.254	.254	.254	.254	.254	.254	.254	.254	.254
28 WGHT BIN2 .3-S-1.	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446
29 WGHT BIN3 1.-S-3.	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281
30 WGHT BIN4 3.-S-10.	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219
31 WGHT BIN5 10.-S-30.	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131
32 WGHT BIN6 30.-S-...	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669
33 RATIO BIN2/BIN4	.139	.139	.139	.139	.139	.139	.139	.139	.139	.139
34 RATIO BIN3/BIN4	.850	.850	.850	.850	.850	.850	.850	.850	.850	.850
35 RATIO BIN5/BIN4	.133	.133	.133	.133	.133	.133	.133	.133	.133	.133
36 RATIO BIN2+3/BIN4	.989	.989	.989	.989	.989	.989	.989	.989	.989	.989
37 RATIO BIN3+5/BIN4	.983	.983	.983	.983	.983	.983	.983	.983	.983	.983
38 FIRST MOMENT OF LOG PSD	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719
39 STAND. DEV. OF LOG PSD	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598
40 COEFF. OF SKEWNESS LOG PSD	.415	.415	.415	.415	.415	.415	.415	.415	.415	.415
41 KURTOSIS OF LOG PSD	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863
42 RATIO STD DEV/MEAN	.244	.244	.244	.244	.244	.244	.244	.244	.244	.244
43 RMS DEV FROM FITTED PSD	-.009	-.009	-.007	-.009	-.009	-.009	-.007	-.009	-.009	-.009
44 FITTED PSD PEAK(MICM) (A)	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770
45 FITTED PSD RISE COEF. (B)	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260
46 FITTED PSD FALL COEF. (C)	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500

ADAPTRONICS,INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS A STARTING POWDER

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
1 CALCIUM PERCENTAGE	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
2 IRON PERCENTAGE	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
3 ALUMINUM PERCENTAGE	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200
4 MAGNESIUM PERCENTAGE	.007	.007	.007	.007	.007	.007	.007	.007	.007	.007
5 MANGANESE PERCENTAGE	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
6 CARBON PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
7 POTASSIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.060*	0.000*	0.000*	0.000*
8 OXYGEN PERCENTAGE	.430	.430	.430	.430	.430	.430	.430	.430	.430	.430
9 TITANIUM PERCENTAGE	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060
10 OXYGEN ANALYSIS (PRCNT)	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760	1.760
11 OXYGEN ANALYSIS +/- PRCNT	.950	.950	.950	.950	.950	.950	.950	.950	.950	.950
12 AVG PART SIZE (MICM)	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200	3.200
13 MAX PART SIZE LENGTH	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000
14 MAX PART SIZE WIDTH	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000
15 SURFACE AREA (M2/GM)	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900
16 20 PRCNTILE SIZE (LOG)	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662	12.662
17 50 PRCNTILE SIZE (LOG)	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036	15.036
18 80 PRCNTILE SIZE (LOG)	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880	17.880
19 95 PRCNTILE SIZE (LOG)	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824	20.824
20 98 PRCNTILE SIZE (LOG)	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667	23.667
21 MAX PART SIZE (LOG)	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000
22 PRCNT .GT.40 MICROMETERS	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
23 PRCNT .GT.20 MICROMETERS	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200	2.200
24 PRCNT .GT.10 MICROMETERS	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800	7.800
25 PRCNT .GT. 5 MICROMETERS	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019	54.019
26 PRCNT .GT. 1 MICROMETERS	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300	93.300
27 WGHT BIN1 .0-S-.3	.254	.254	.254	.254	.254	.254	.254	.254	.254	.254
28 WGHT BIN2 .3-S-1.	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446	6.446
29 WGHT BIN3 1.-S-3.	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281	39.281
30 WGHT BIN4 3.-S-10.	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219	46.219
31 WGHT BIN5 10.-S-30.	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131	6.131
32 WGHT BIN6 30.-S-...	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669	1.669
33 RATIO BIN2/BIN4	.139	.139	.139	.139	.139	.139	.139	.139	.139	.139
34 RATIO BIN3/BIN4	.850	.850	.850	.850	.850	.850	.850	.850	.850	.850
35 RATIO BIN5/BIN4	.133	.133	.133	.133	.133	.133	.133	.133	.133	.133
36 RATIO BIN2+3/BIN4	.989	.989	.989	.989	.989	.989	.989	.989	.989	.989
37 RATIO BIN3+5/BIN4	.983	.983	.983	.983	.983	.983	.983	.983	.983	.983
38 FIRST MOMENT OF LOG PSD	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719	14.719
39 STAND. DEV. OF LOG PSD	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598	3.598
40 COEF. OF SKEWNESS LOG PSD	.415	.415	.415	.415	.415	.415	.415	.415	.415	.415
41 KURTOSIS OF LOG PSD	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863	4.863
42 RATIO STD DEV/MEAN	.244	.244	.244	.244	.244	.244	.244	.244	.244	.244
43 RMS DEV FROM FITTED PSD	-.009	-.009	-.009	-.009	-.009	-.009	-.009	-.009	-.009	-.009
44 FITTED PSD PEAK(MICM) (A)	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770	14.770
45 FITTED PSD RISE COEF. (B)	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260	4.260
46 FITTED PSD FALL COEF. (C)	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS A STARTING POWDER

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
1 CALCIUM PERCENTAGE	.030	.030	.030	.030	.030	.030	.010	.010	.010	.030
2 IRON PERCENTAGE	.300	.300	.300	.300	.300	.300	1.500	1.500	1.500	.300
3 ALUMINUM PERCENTAGE	.400	.400	.400	.400	.400	.400	.060	.060	.060	.400
4 MAGNESIUM PERCENTAGE	.003	.003	.003	.003	.003	.003	.005	.005	.005	.003
5 MANGANESE PERCENTAGE	.020	.020	.020	.020	.020	.020	.040	.040	.040	.020
6 CARBON PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	.130	.130	.130	0.000*
7 POTASSIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	.100	.100	.100	0.000*
8 OXYGEN PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	.340	.340	.340	0.000*
9 TITANIUM PERCENTAGE	.050	.050	.050	.050	.050	.050	.060	.060	.060	.050
10 OXYGEN ANALYSIS (PRCNT)	.140	.140	.140	.140	.140	.140	.500	.500	.500	.140
11 OXYGEN ANALYSIS +/- PRCNT	.150	.150	.150	.150	.150	.150	.380	.380	.380	1.060
12 AVG PART SIZE (MICM)	30.000	30.000	30.000	30.000	30.000	30.000	8.200	8.200	8.200	30.000
13 MAX PART SIZE LENGTH	125.000	125.000	125.000	125.000	125.000	125.000	250.000	250.000	250.000	125.000
14 MAX PART SIZE WIDTH	125.000	125.000	125.000	125.000	125.000	125.000	190.000	190.000	190.000	125.000
15 SURFACE AREA (M2/GM)	.300	.300	.300	.300	.300	.300	1.200	1.200	1.200	.300
16 20 PRCNTILE SIZE (LOG)	21.250	21.250	21.250	21.250	21.250	21.250	14.622	14.622	14.622	21.250
17 50 PRCNTILE SIZE (LOG)	24.667	24.667	24.667	24.667	24.667	24.667	19.117	19.117	19.117	24.667
18 80 PRCNTILE SIZE (LOG)	26.207	26.207	26.207	26.207	26.207	26.207	21.347	21.347	21.347	26.207
19 95 PRCNTILE SIZE (LOG)	27.632	27.632	27.632	27.632	27.632	27.632	23.103	23.103	23.103	27.632
20 98 PRCNTILE SIZE (LOG)	28.227	28.227	28.227	28.227	28.227	28.227	24.333	24.333	24.333	28.227
21 MAX PART SIZE (LOG)	31.000	31.000	31.000	31.000	31.000	31.000	33.000	33.000	33.000	31.000
22 PRCNT .GT.40 MICROMETERS	22.800	22.800	22.800	22.800	22.800	22.800	.800	.800	.800	22.800
23 PRCNT .GT.20 MICROMETERS	70.000	70.000	70.000	70.000	70.000	70.000	5.300	5.300	5.300	70.000
24 PRCNT .GT.10 MICROMETERS	85.300	85.300	85.300	85.300	85.300	85.300	38.700	38.700	38.700	85.300
25 PRCNT .GT. 5 MICROMETERS	98.961	98.961	98.961	98.961	98.961	98.961	79.335	79.335	79.335	98.961
26 PRCNT .GT. 1 MICROMETERS	100.000	100.000	100.000	100.000	100.000	100.000	97.100	97.100	97.100	100.000
27 WGHT BIN1 .0-S-.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28 WGHT BIN2 .3-S-1.	0.000	0.000	0.000	0.000	0.000	0.000	2.900	2.900	2.900	0.000
29 WGHT BIN3 1.-S-3.	1.039	1.039	1.039	1.039	1.039	1.039	17.765	17.765	17.765	1.039
30 WGHT BIN4 3.-S-10.	13.661	13.661	13.661	13.661	13.661	13.661	40.635	40.635	40.635	13.661
31 WGHT BIN5 10.-S-30.	36.850	36.850	36.850	36.850	36.850	36.850	37.224	37.224	37.224	36.850
32 WGHT BIN6 30.-S-...	48.450	48.450	48.450	48.450	48.450	48.450	1.476	1.476	1.476	48.450
33 RATIO BIN2/BIN4	0.000	0.000	0.000	0.000	0.000	0.000	.071	.071	.071	0.000
34 RATIO BIN3/BIN4	.076	.076	.076	.076	.076	.076	.437	.437	.437	.076
35 RATIO BIN5/BIN4	2.697	2.697	2.697	2.697	2.697	2.697	.916	.916	.916	2.697
36 RATIO BIN2+3/BIN4	.076	.076	.076	.076	.076	.076	.509	.509	.509	.076
37 RATIO BIN3+5/BIN4	2.774	2.774	2.774	2.774	2.774	2.774	1.353	1.353	1.353	2.774
38 FIRST MOMENT OF LOG PSD	23.244	23.244	23.244	23.244	23.244	23.244	17.676	17.676	17.676	23.244
39 STAND. DEV. OF LOG PSD	3.190	3.190	3.190	3.190	3.190	3.190	3.870	3.870	3.870	3.190
40 COEF. OF SKEWNESS LOG PSD	-1.054	-1.054	-1.054	-1.054	-1.054	-1.054	-.551	-.551	-.551	-1.054
41 KURTOSIS OF LOG PSD	3.570	3.570	3.570	3.570	3.570	3.570	2.869	2.869	2.869	3.570
42 RATIO STD DEV/MEAN	.137	.137	.137	.137	.137	.137	.219	.219	.219	.137
43 RMS DEV FROM FITTED PSD	-.044	-.044	-.044	-.044	-.044	-.044	-.007	-.007	-.007	-.044
44 FITTED PSD PEAK(MICM) (A)	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
45 FITTED PSD RISE COEF. (B)	.900	.900	.900	.900	.900	.900	1.010	1.010	1.010	.900
46 FITTED PSD FALL COEF. (C)	.500	.500	.500	.500	.500	.500	3.210	3.210	3.210	.500

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS A STARTING POWDER

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
PARAMETER NUMBER AND NAME					
1 CALCIUM PERCENTAGE	.030	0.000	0.000	0.000	0.000
2 IRON PERCENTAGE	.550	.420	.420	.420	.420
3 ALUMINUM PERCENTAGE	.200	0.000	0.000	0.000	0.000
4 MAGNESIUM PERCENTAGE	.002	.002	.002	.002	.002
5 MANGANESE PERCENTAGE	.016	.007	.007	.007	.007
6 CARBON PERCENTAGE	.130	0.000*	0.000*	0.000*	0.000*
7 POTASSIUM PERCENTAGE	.100	0.000*	0.000*	0.000*	0.000*
8 OXYGEN PERCENTAGE	.340	0.000	0.000	0.000	0.000
9 TITANIUM PERCENTAGE	.045	0.000	0.000	0.000	0.000
10 OXYGEN ANALYSIS (PRCNT)	.500	.410	.410	.410	.410
11 OXYGEN ANALYSIS +/- PRCNT	.760	.780	.700	.700	.700
12 AVG PART SIZE (MICM)	10.000	7.000	7.000	7.000	7.000
13 MAX PART SIZE LENGTH	220.000	120.000	120.000	120.000	120.000
14 MAX PART SIZE WIDTH	160.000	50.000	50.000	50.000	50.000
15 SURFACE AREA (M2/GM)	1.200	1.400	1.400	1.400	1.400
16 20 PRCNTILE SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
17 50 PRCNTILE SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
18 80 PRCNTILE SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
19 95 PRCNTILE SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
20 98 PRCNTILE SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
21 MAX PART SIZE (LOG)	0.000*	0.000*	0.000*	0.000*	0.000*
22 PRCNT .GT.40 MICROMETERS	0.000*	0.000*	0.000*	0.000*	0.000*
23 PRCNT .GT.20 MICROMETERS	0.000*	0.000*	0.000*	0.000*	0.000*
24 PRCNT .GT.10 MICROMETERS	0.000*	0.000*	0.000*	0.000*	0.000*
25 PRCNT .GT. 5 MICROMETERS	0.000*	0.000*	0.000*	0.000*	0.000*
26 PRCNT .GT. 1 MICROMETERS	0.000*	0.000*	0.000*	0.000*	0.000*
27 WGHT BIN1 .0-S-.3	0.000*	0.000*	0.000*	0.000*	0.000*
28 WGHT BIN2 .3-S-1.	0.000*	0.000*	0.000*	0.000*	0.000*
29 WGHT BIN3 1.-S-3.	0.000*	0.000*	0.000*	0.000*	0.000*
30 WGHT BIN4 3.-S-10.	0.000*	0.000*	0.000*	0.000*	0.000*
31 WGHT BIN5 10.-S-30.	0.000*	0.000*	0.000*	0.000*	0.000*
32 WGHT BIN6 30.-S-...	0.000*	0.000*	0.000*	0.000*	0.000*
33 RATIO BIN2/BIN4	0.000*	0.000*	0.000*	0.000*	0.000*
34 RATIO BIN3/BIN4	0.000*	0.000*	0.000*	0.000*	0.000*
35 RATIO BIN5/BIN4	0.000*	0.000*	0.000*	0.000*	0.000*
36 RATIO BIN2+3/BIN4	0.000*	0.000*	0.000*	0.000*	0.000*
37 RATIO BIN3+5/BIN4	0.000*	0.000*	0.000*	0.000*	0.000*
38 FIRST MOMENT OF LOG PSD	0.000*	0.000*	0.000*	0.000*	0.000*
39 STAND. DEV. OF LOG PSD	0.000*	0.000*	0.000*	0.000*	0.000*
40 COEF. OF SKEWNESS LOG PSD	0.000*	0.000*	0.000*	0.000*	0.000*
41 KURTOSIS OF LOG PSD	0.000*	0.000*	0.000*	0.000*	0.000*
42 RATIO STD DEV/MEAN	0.000*	0.000*	0.000*	0.000*	0.000*
43 RMS DEV FROM FITTED PSD	0.000*	0.000*	0.000*	0.000*	0.000*
44 FITTED PSD PEAK(MICM) (A)	0.000*	0.000*	0.000*	0.000*	0.000*
45 FITTED PSD RISE COEF. (B)	0.000*	0.000*	0.000*	0.000*	0.000*
46 FITTED PSD FALL COEF. (C)	0.000*	0.000*	0.000*	0.000*	0.000*

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

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TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS F POWDER PREPARATION

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
PARAMETER NUMBER AND NAME										
47 CALCIUM PERCENTAGE	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
48 IRON PERCENTAGE	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
49 ALUMINUM PERCENTAGE	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200
50 MAGNESIUM PERCENTAGE	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
51 MANGANESE PERCENTAGE	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
52 TITANIUM PERCENTAGE	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060
53 VANADIUM PERCENTAGE	.100	.100	.100	.100	.100	.100	.100	.100	.100	.100
54 OXYGEN ANALYSIS (PRCNT)	2.970	2.970	2.970	2.970	2.970	2.970	2.970	2.970	2.970	2.970
55 OXYGEN ANALYSIS +/- PRCNT	1.175	1.175	1.175	1.175	1.175	1.175	1.175	1.175	1.175	1.175
56 BALL MILL TIME (HRS)	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000
57 VIBRATION MILL TIME (HRS)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58 AIR CLASSIFY (YES/NO)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59 MEDIA QUANTITY (AL2O3,KG)	10.100	10.100	10.100	10.100	10.100	10.100	10.100	10.100	10.100	10.100
60 ADDITIVES FE2O3	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
61 ADDITIVES BORON	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
62 AVG PART SIZE (MICM)	3.100	3.100	3.100	3.100	3.100	3.100	3.100	3.100	3.100	3.100
63 MAX PART SIZE LENGTH	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000	275.000
64 MAX PART SIZE WIDTH	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000	250.000
65 SURFACE AREA (M2/GM)	6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500
66 STORAGE TIME (HOURS)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
67 20 PRCNTILE SIZE (LOG)	10.087	10.087	10.087	10.087	10.087	10.087	10.087	10.087	10.087	10.087
68 50 PRCNTILE SIZE (LOG)	14.867	14.867	14.867	14.867	14.867	14.867	14.867	14.867	14.867	14.867
69 80 PRCNTILE SIZE (LOG)	17.747	17.747	17.747	17.747	17.747	17.747	17.747	17.747	17.747	17.747
70 95 PRCNTILE SIZE (LOG)	20.192	20.192	20.192	20.192	20.192	20.192	20.192	20.192	20.192	20.192
71 98 PRCNTILE SIZE (LOG)	21.563	21.563	21.563	21.563	21.563	21.563	21.563	21.563	21.563	21.563
72 MAX PART SIZE (LOG)	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000	34.000
73 PRCNT .GT.40 MICROMETERS	.400	.400	.400	.400	.400	.400	.400	.400	.400	.400
74 PRCNT .GT.20 MICROMETERS	.800	.800	.800	.800	.800	.800	.800	.800	.800	.800
75 PRCNT .GT.10 MICROMETERS	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
76 PRCNT .GT. 5 MICROMETERS	51.160	51.160	51.160	51.160	51.160	51.160	51.160	51.160	51.160	51.160
77 PRCNT .GT. 1 MICROMETERS	80.200	80.200	80.200	80.200	80.200	80.200	80.200	80.200	80.200	80.200
78 WGHT BIN1 .0-S-.3	2.994	2.994	2.994	2.994	2.994	2.994	2.994	2.994	2.994	2.994
79 WGHT BIN2 .3-S-1.	16.806	16.806	16.806	16.806	16.806	16.806	16.806	16.806	16.806	16.806
80 WGHT BIN3 1.-S-3.	29.040	29.040	29.040	29.040	29.040	29.040	29.040	29.040	29.040	29.040
81 WGHT BIN4 3.-S-10.	45.660	45.660	45.660	45.660	45.660	45.660	45.660	45.660	45.660	45.660
82 WGHT BIN5 10.-S-30.	4.977	4.977	4.977	4.977	4.977	4.977	4.977	4.977	4.977	4.977
83 WGHT BIN6 30.-S-...	.523	.523	.523	.523	.523	.523	.523	.523	.523	.523
84 RATIO BIN2/BIN4	.368	.368	.368	.368	.368	.368	.368	.368	.368	.368
85 RATIO BIN3/BIN4	.636	.636	.636	.636	.636	.636	.636	.636	.636	.636
86 RATIO BIN5/BIN4	.109	.109	.109	.109	.109	.109	.109	.109	.109	.109
87 RATIO BIN2+3/BIN4	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.004
88 RATIO BIN3+5/BIN4	.745	.745	.745	.745	.745	.745	.745	.745	.745	.745
89 FIRST MOMENT OF LOG PSD	13.574	13.574	13.574	13.574	13.574	13.574	13.574	13.574	13.574	13.574
90 STAND. DEV. OF LOG PSD	4.520	4.520	4.520	4.520	4.520	4.520	4.520	4.520	4.520	4.520
91 COEF. OF SKEWNESS LOG PSD	-.463	-.463	-.463	-.463	-.463	-.463	-.463	-.463	-.463	-.463
92 KURTOSIS OF LOG PSD	3.014	3.014	3.014	3.014	3.014	3.014	3.014	3.014	3.014	3.014
93 RATIO STD DEV/MEAN	.333	.333	.333	.333	.333	.333	.333	.333	.333	.333
94 RMS DEV FROM FITTED PSD	.012	.012	.012	.012	.012	.012	.012	.012	.012	.012
95 FITTED PSD PEAK(MICM) (A)	15.660	15.660	15.660	15.660	15.660	15.660	15.660	15.660	15.660	15.660
96 FITTED PSD RISE COEF. (B)	1.090	1.090	1.090	1.090	1.090	1.090	1.090	1.090	1.090	1.090
97 FITTED PSD FALL COEF. (C)	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500

ADAPTRONICS,INC.
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FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS B POWDER PREPARATION

SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
47 CALCIUM PERCENTAGE	.030	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
48 IRON PERCENTAGE	5.000	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
49 ALUMINUM PERCENTAGE	.200	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
50 MAGNESIUM PERCENTAGE	.005	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
51 MANGANESE PERCENTAGE	.050	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
52 TITANIUM PERCENTAGE	.060	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
53 VANADIUM PERCENTAGE	.100	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
54 OXYGEN ANALYSIS (PRCNT)	2.970	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
55 OXYGEN ANALYSIS +/- PRCNT	1.175	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
56 BALL MILL TIME (HRS)	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000
57 VIBRATION MILL TIME (HRS)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58 AIR CLASSIFY (YES/NO)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59 MEDIA QUANTITY (AL2O3,KG)	10.100	8.600	8.600	8.600	8.600	9.700	9.700	12.000	12.000	12.000
60 ADDITIVES FE2O3	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
61 ADDITIVES BORON	0.000*	.750	.750	.750	.750	.500	.500	.200	.200	.200
62 AVG PART SIZE (MICM)	3.100	2.800	2.800	2.800	2.800	3.000	3.000	3.300	3.300	3.300
63 MAX PART SIZE LENGTH	275.000	200.000	200.000	200.000	200.000	225.000	225.000	200.000	200.000	200.000
64 MAX PART SIZE WIDTH	250.000	200.000	200.000	200.000	200.000	225.000	225.000	175.000	175.000	175.000
65 SURFACE AREA (M2/GM)	6.500	7.200	7.200	7.200	7.200	7.500	7.500	7.100	7.100	7.100
66 STORAGE TIME (HOURS)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
67 20 PRCNTILE SIZE (LOG)	10.087	9.118	9.118	9.118	9.118	9.478	9.478	10.957	10.957	10.957
68 50 PRCNTILE SIZE (LOG)	14.867	14.500	14.500	14.500	14.500	14.808	14.808	15.234	15.234	15.234
69 80 PRCNTILE SIZE (LOG)	17.747	17.526	17.526	17.526	17.526	17.679	17.679	17.979	17.979	17.979
70 95 PRCNTILE SIZE (LOG)	20.192	20.103	20.103	20.103	20.103	20.370	20.370	20.545	20.545	20.545
71 98 PRCNTILE SIZE (LOG)	21.563	21.267	21.267	21.267	21.267	21.867	21.867	22.000	22.000	22.000
72 MAX PART SIZE (LOG)	34.000	33.000	33.000	33.000	33.000	33.000	33.000	32.000	32.000	32.000
73 PRCNT .GT.40 MICROMETERS	.400	.300	.300	.300	.300	.300	.300	.200	.200	.200
74 PRCNT .GT.20 MICROMETERS	.800	.700	.700	.700	.700	.900	.900	1.300	1.300	1.300
75 PRCNT .GT.10 MICROMETERS	5.500	5.300	5.300	5.300	5.300	6.000	6.000	6.800	6.800	6.800
76 PRCNT .GT. 5 MICROMETERS	51.160	46.760	46.760	46.760	46.760	50.558	50.558	56.190	56.190	56.190
77 PRCNT .GT. 1 MICROMETERS	80.200	77.000	77.000	77.000	77.000	78.800	78.800	82.200	82.200	82.200
78 WGHT BIN1 .0-S-.3	2.994	3.571	3.571	3.571	3.571	4.579	4.579	3.202	3.202	3.202
79 WGHT BIN2 .3-S-1.	16.806	19.429	19.429	19.429	19.429	16.621	16.621	14.598	14.598	14.598
80 WGHT BIN3 1.-S-3.	29.040	30.240	30.240	30.240	30.240	28.242	28.242	26.010	26.010	26.010
81 WGHT BIN4 3.-S-10.	45.660	41.460	41.460	41.460	41.460	44.558	44.558	49.390	49.390	49.390
82 WGHT BIN5 10.-S-30.	4.977	4.877	4.877	4.877	4.877	5.554	5.554	6.308	6.308	6.308
83 WGHT BIN6 30.-S-...	.523	.423	.423	.423	.423	.446	.446	.492	.492	.492
84 RATIO BIN2/BIN4	.368	.469	.469	.469	.469	.373	.373	.296	.296	.296
85 RATIO BIN3/BIN4	.636	.729	.729	.729	.729	.634	.634	.527	.527	.527
86 RATIO BIN5/BIN4	.109	.118	.118	.118	.118	.125	.125	.128	.128	.128
87 RATIO BIN2+3/BIN4	1.004	1.198	1.198	1.198	1.198	1.007	1.007	.822	.822	.822
88 RATIO BIN3+5/BIN4	.745	.847	.847	.847	.847	.758	.758	.654	.654	.654
89 FIRST MOMENT OF LOG PSD	13.574	13.179	13.179	13.179	13.179	13.447	13.447	13.967	13.967	13.967
90 STAND. DEV. OF LOG PSD	4.520	4.572	4.572	4.572	4.572	4.711	4.711	4.494	4.494	4.494
91 COEF. OF SKEWNESS LOG PSD	-.463	-.383	-.383	-.383	-.393	-.541	-.541	-.613	-.613	-.613
92 KURTOSIS OF LOG PSD	3.014	2.754	2.754	2.754	2.754	2.954	2.954	3.120	3.120	3.120
93 RATIO STD DEV/MEAN	.333	.347	.347	.347	.347	.350	.350	.322	.322	.322
94 RMS DEV FROM FITTED PSD	.012	.011	.011	.011	.011	.015	.015	.013	.013	.013
95 FITTED PSD PEAK(MICM) (A)	15.660	15.460	15.460	15.460	15.460	15.590	15.590	15.930	15.930	15.930
96 FITTED PSD RISE COFF. (B)	1.090	.920	.920	.920	.920	1.130	1.130	1.250	1.250	1.250
97 FITTED PSD FALL COEF. (C)	1.500	1.520	1.520	1.520	1.520	1.470	1.470	1.520	1.520	1.520

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS B POWDER PREPARATION

SUPPROCESS DESIGNATION	ABCFG	ABDFG	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABCFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
PARAMETER NUMBER AND NAME										
47 CALCIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
48 IRON PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
49 ALUMINUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
50 MAGNESIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
51 MANGANESE PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
52 TITANIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
53 VANADIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
54 OXYGEN ANALYSIS (PRCNT)	0.000*	1.790	1.790	1.790	1.790	0.000*	0.000*	11.110	11.110	1.790
55 OXYGEN ANALYSIS +/- PRCNT	0.000*	.895	.895	.895	.895	0.000*	0.000*	4.000	4.000	.895
56 BALL MILL TIME (HRS)	16.000	16.000	16.000	16.000	16.000	0.000	16.000	0.000	0.000	16.000
57 VIBRATION MILL TIME (HRS)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.000	4.000	0.000
58 AIR CLASSIFY (YES/NO)	0.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	1.000
59 MEDIA QUANTITY (AL2O3,KG)	9.700	12.000	12.000	12.000	12.000	0.000	10.100	0.000	0.000	13.860
60 ADDITIVES FE2O3	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
61 ADDITIVES BORON	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	.002	.002	0.000*
62 AVG PART SIZE (MICM)	5.300	4.700	4.700	4.700	4.700	7.000	0.000*	6.300	6.300	4.700
63 MAX PART SIZE LENGTH	0.000*	31.000	31.000	31.000	31.000	0.000*	0.000*	250.000	250.000	31.000
64 MAX PART SIZE WIDTH	0.000*	31.000	31.000	31.000	31.000	0.000*	0.000*	190.000	190.000	31.000
65 SURFACE AREA (M2/GM)	3.000	3.400	3.400	3.400	3.400	1.000	0.000*	11.100	11.100	3.400
66 STORAGE TIME (HOURS)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
67 20 PRCNTILE SIZE (LOG)	14.290	13.731	13.731	13.731	13.731	17.064	13.027	13.156	13.156	13.731
68 50 PRCNTILE SIZE (LOG)	17.273	16.688	16.688	16.688	16.688	18.401	16.473	18.000	18.000	16.688
69 80 PRCNTILE SIZE (LOG)	21.206	19.236	19.236	19.236	19.236	19.538	20.045	20.438	20.438	19.236
70 95 PRCNTILE SIZE (LOG)	23.846	21.674	21.674	21.674	21.674	20.757	22.943	22.147	22.147	21.674
71 98 PRCNTILE SIZE (LOG)	25.167	22.941	22.941	22.941	22.941	21.520	24.909	23.083	23.083	22.941
72 MAX PART SIZE (LOG)	32.000	25.000	25.000	25.000	25.000	23.000	31.000	33.000	33.000	25.000
73 PRCNT .GT.40 MICROMETERS	1.000	0.000	0.000	0.000	0.000	0.000	1.200	.300	.300	0.000
74 PRCNT .GT.20 MICROMETERS	8.300	1.900	1.900	1.900	1.900	0.000	4.800	2.100	2.100	1.900
75 PRCNT .GT.10 MICROMETERS	28.200	14.500	14.500	14.500	14.500	10.300	20.300	25.300	25.300	14.500
76 PRCNT .GT. 5 MICROMETERS	77.026	72.902	72.902	72.902	72.902	95.929	66.178	74.220	74.220	72.902
77 PRCNT .GT. 1 MICROMETERS	92.400	91.800	91.800	91.800	91.800	99.900	91.400	87.900	87.900	91.800
78 WEHT BIN1 .0-S-.3	.762	1.262	1.262	1.262	1.262	0.000	2.393	2.816	2.816	1.262
79 WEHT BIN2 .3-S-1.	6.838	6.938	6.938	6.938	6.938	.100	6.207	9.284	9.284	6.938
80 WEHT BIN3 1.-S-3.	15.374	18.898	18.898	18.898	18.898	3.971	25.222	13.680	13.680	18.898
81 WEHT BIN4 3.-S-10.	48.826	58.402	58.402	58.402	58.402	85.629	45.878	48.920	48.920	58.402
82 WEHT BIN5 10.-S-30.	25.494	14.270	14.270	14.270	14.270	10.300	18.147	24.708	24.708	14.270
83 WEHT BIN6 30.-S-...	2.706	.230	.230	.230	.230	0.000	2.153	.592	.592	.230
84 RATIO BIN2/BIN4	.140	.119	.119	.119	.119	.001	.135	.190	.190	.119
85 RATIO BIN3/BIN4	.315	.324	.324	.324	.324	.046	.550	.280	.280	.324
86 RATIO BIN5/BIN4	.522	.244	.244	.244	.244	.120	.396	.505	.505	.244
87 RATIO BIN2+3/BIN4	.455	.442	.442	.442	.442	.048	.685	.469	.469	.442
88 RATIO BIN3+5/BIN4	.837	.568	.568	.568	.568	.167	.945	.785	.785	.568
89 FIRST MOMENT OF LOG PSD	16.731	15.704	15.704	15.704	15.704	17.714	15.754	16.151	16.151	15.704
90 STAND. DEV. OF LOG PSD	4.471	3.932	3.932	3.932	3.932	1.719	4.590	4.741	4.741	3.932
91 COEF. OF SKEWNESS LOG PSD	-.513	-.881	-.881	-.881	-.881	-.917	-.469	-1.024	-1.024	-.881
92 KURTOSIS OF LOG PSD	3.324	4.097	4.097	4.097	4.097	5.432	3.744	3.717	3.717	4.097
93 RATIO STD DEV/MEAN	.267	.250	.250	.250	.250	.097	.291	.294	.294	.250
94 RMS DEV FROM FITTED PSD	.011	.008	.008	.008	.008	.008	.005	.005	.005	.008
95 FITTED PSD PEAK(MICM) (A)	17.650	16.720	16.720	16.720	16.720	18.230	16.600	19.240	19.240	16.720
96 FITTED PSD RISE COEF. (B)	2.360	3.490	3.490	3.490	3.490	3.810	3.050	.960	.960	3.490
97 FITTED PSD FALL COEF. (C)	.470	.590	.590	.590	.590	3.160	.370	3.040	3.040	.590

ADAPTRONICS,INC. SLIP CASTING ADAPTIVE CONTROL JCB542

DATA BASE SUPPLIED BY AIRESEARCH CASTING COMPANY TORRANCE , CALIFORNIA

FEBRUARY 1979 REVISED 12/04/79

SUBPROCESS B POWDER PREPARATION

PARAMETER NUMBER AND NAME					
SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	41212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
47 CALCIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
48 IRON PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
49 ALUMINUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
50 MAGNESIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
51 MANGANESE PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
52 TITANIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
53 VANADIUM PERCENTAGE	0.000*	0.000*	0.000*	0.000*	0.000*
54 OXYGEN ANALYSIS (PRCNT)	0.000*	0.000*	0.000*	2.080	0.000*
55 OXYGEN ANALYSIS +/- PRCNT	0.000*	0.000*	0.000*	.460	0.000*
56 BALL MILL TIME (HRS)	16.000	16.000	16.000	16.000	15.000
57 VIBRATION MILL TIME (HRS)	0.000	0.000	0.000	0.000	0.000
58 AIR CLASSIFY (YES/NO)	0.000	0.000	0.000	0.000	0.000
59 MEDIA QUANTITY (AL2O3,KG)	13.860	13.860	13.860	13.860	13.860
60 ADDITIVES FE2O3	.030	.030	.030	.030	0.000
61 ADDITIVES BORON	0.000*	0.000*	0.000*	0.000*	0.000*
62 AVG PART SIZE (MICM)	4.800	4.200	4.700	4.600	4.600
63 MAX PART SIZE LENGTH	22.000	25.000	20.000	17.000	22.000
64 MAX PART SIZE WIDTH	22.000	25.000	20.000	17.000	22.000
65 SURFACE AREA (M2/GM)	4.300	3.800	4.000	4.300	4.300
66 STORAGE TIME (HOURS)	0.000*	0.000*	0.000*	0.000*	0.000*
67 20 PRCNTILE SIZE (LOG)	15.542	12.200	15.231	15.448	16.150
68 50 PRCNTILE SIZE (LOG)	17.800	17.278	17.735	17.595	17.872
69 80 PRCNTILE SIZE (LOG)	20.563	20.588	19.920	19.435	20.167
70 95 PRCNTILE SIZE (LOG)	22.727	22.667	22.000	21.375	22.324
71 98 PRCNTILE SIZE (LOG)	23.690	23.500	23.000	22.227	23.333
72 MAX PART SIZE (LOG)	25.000	25.000	24.000	24.000	25.000
73 PRCNT .GT.40 MICROMETERS	0.000	0.000	0.000	0.000	0.000
74 PRCNT .GT.20 MICROMETERS	3.500	3.000	2.000	.300	2.500
75 PRCNT .GT.10 MICROMETERS	24.500	25.000	19.000	13.500	21.500
76 PRCNT .GT. 5 MICROMETERS	85.765	68.311	81.936	83.920	88.797
77 PRCNT .GT. 1 MICROMETERS	97.600	86.300	92.200	94.500	97.700
78 WGHT BIN1 .0-S-.3	0.000	2.816	3.616	.885	.385
79 WGHT BIN2 .3-S-1.	2.400	10.884	4.184	4.615	1.915
80 WGHT BIN3 1.-S-3.	11.835	17.989	10.264	10.580	8.903
81 WGHT BIN4 3.-S-10.	61.265	43.311	62.936	70.420	67.297
82 WGHT BIN5 10.-S-30.	24.270	24.770	19.000	13.500	21.270
83 WGHT BIN6 30.-S-...	.230	.230	0.000	0.000	.230
84 RATIO BIN2/BIN4	.039	.251	.066	.066	.028
85 RATIO BIN3/BIN4	.193	.415	.163	.150	.132
86 RATIO BIN5/BIN4	.396	.572	.302	.192	.316
87 RATIO BIN2+3/BIN4	.232	.667	.230	.216	.161
88 RATIO BIN3+5/BIN4	.589	.987	.465	.342	.448
89 FIRST MOMENT OF LOG PSD	17.265	15.751	16.449	16.535	17.302
90 STAND. DEV. OF LOG PSD	3.200	5.003	4.159	3.386	3.048
91 COEF. OF SKEWNESS LOG PSD	-.588	-.827	-1.574	-1.516	-1.080
92 KURTOSIS OF LOG PSD	3.958	3.123	6.074	6.098	6.111
93 RATIO STD DEV/MEAN	.185	.318	.253	.205	.176
94 RMS DEV FROM FITTED PSD	.015	.004	.012	.012	.013
95 FITTED PSD PEAK(MICM) (A)	17.720	18.850	17.840	17.520	17.630
96 FITTED PSD RISE COEF. (B)	4.570	.790	3.910	5.000	5.000
97 FITTED PSD FALL COEF. (C)	.510	1.800	.750	.850	.670

ADAPTRONICS,INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

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FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS E SLIP PREPARATION

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
PARAMETER NUMBER AND NAME										
98 SOLIDS CNTNT(WGHT PRCNT)	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
99 DEFLOCCULANT (WGHT. PRCNT)	.042	.042	.042	.042	.042	.042	.042	.042	.042	.042
100 ADDITIVE ACID (WGHT. PR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
101 ADDITIVE FE2O3 (WGHT. PR	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
102 ADDITIVE NH4OH (WGHT. PR	0.000	0.000	0.000	0.000	0.000	.012	.012	.012	.012	.012
103 AGING TIME (DAYS)	13.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000
104 TEMPERATURE (DEG. F)	69.000	69.000	69.000	69.000	69.000	72.000	72.000	72.000	72.000	72.000
105 PH	5.900	5.900	5.900	5.900	5.900	5.800	5.800	5.800	5.800	5.800
106 VISCOSITY 1/60 (CPS)	100.000	100.000	100.000	100.000	100.000	79.000	79.000	79.000	79.000	79.000
107 VISCOSITY 1/30 (CPS)	133.000	133.000	133.000	133.000	133.000	102.000	102.000	102.000	102.000	102.000
108 VISCOSITY 1/12 (CPS)	192.000	192.000	192.000	192.000	192.000	150.000	150.000	150.000	150.000	150.000
109 THIXOTROPIC INDEX	1.750	1.750	1.750	1.750	1.750	1.900	1.900	1.900	1.900	1.900

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SUBPROCESS D SLIP PREPARATION

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	AEDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
98 SOLIDS CNTNT(WGHT PRCNT)	75.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000
99 DEFLOCCULANT (WGHT. PRCNT)	.042	.030	.030	.030	.030	.067	.067	.042	.042	.042
100 ADDITIVE ACID (WGHT. PR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
101 ADDITIVE FE2O3 (WGHT. PR	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
102 ADDITIVE NH4OH (WGHT. PR	.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
103 AGING TIME (DAYS)	13.000	15.000	6.000	6.000	6.000	5.000	5.000	5.000	5.000	5.000
104 TEMPERATURE (DEG. F)	72.000	69.000	68.000	68.000	68.000	69.000	69.000	69.000	69.000	69.000
105 PH	5.800	5.100	5.100	5.100	5.100	5.700	5.700	5.100	5.100	5.100
106 VISCOSITY 1/60 (CPS)	79.000	105.000	65.000	65.000	65.000	94.000	94.000	95.000	95.000	95.000
107 VISCOSITY 1/30 (CPS)	102.000	150.000	88.000	88.000	88.000	135.000	135.000	128.000	128.000	128.000
108 VISCOSITY 1/12 (CPS)	150.000	250.000	140.000	140.000	140.090	240.000	240.000	205.000	205.000	205.000
109 THIXOTROPIC INDEX	1.900	2.380	2.160	2.160	2.160	2.550	2.550	2.160	2.160	2.160

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SUBPROCESS D SLIP PREPARATION

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
PARAMETER NUMBER AND NAME										
98 SOLIDS CNTNT (WGHT PRCNT)	75.000	75.000	75.000	75.000	75.000	52.000	75.000	70.000	70.000	75.000
99 DEFLOCCULANT (WGHT. PRCNT)	.031	.031	.031	.031	.031	.024	.031	.005	.009	.031
100 ADDITIVE ACID (WGHT. PR	.003	.004	.004	.004	0.000	0.000	.009	0.000	0.000	.006
101 ADDITIVE FE2O3 (WGHT. PR	.030	.030	.030	.030	.030	.030	.030	.030	.030	0.000
102 ADDITIVE NH4OH (WGHT. PR	.004	.011	.011	.011	0.000	0.000	0.000	0.000	0.000	0.000
103 AGING TIME (DAYS)	13.000	12.000	12.000	12.000	6.000	16.000	18.000	40.000	40.000	6.000
104 TEMPERATURE (DEG. F)	74.000	71.000	71.000	71.000	72.000	75.000	66.000	72.000	72.000	71.000
105 PH	6.300	6.300	6.300	6.300	6.200	7.100	6.500	6.400	6.400	5.400
106 VISCOSITY 1/60 (CPS)	95.000	97.000	97.000	97.000	67.000	17.000	83.000	16.000	16.000	45.000
107 VISCOSITY 1/30 (CPS)	110.000	124.000	124.000	124.000	76.000	21.000	102.000	16.000	16.000	50.000
108 VISCOSITY 1/12 (CPS)	135.000	175.000	175.000	175.000	102.000	32.500	151.000	27.000	27.000	62.500
109 THIXOTROPIC INDEX	1.420	1.800	1.800	1.800	1.490	1.910	1.820	1.670	1.670	1.390

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SUBPROCESS E SLIP PREPARATION

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
PARAMETER NUMBER AND NAME					
58 SOLIDS CNTNT(WGHT PRCNT)	75.000	75.000	75.000	75.000	75.000
59 DEFLOCCULANT (WGHT. PRCNT)	0.000	.031	.031	.031	.031
100 ADDITIVE ACID (WGHT. PR	0.000	0.000	0.000	.009	0.000
101 ADDITIVE FE2O3 (WGHT. PR	0.000	0.000	0.000	0.000	0.000
102 ADDITIVE NH4OH (WGHT. PR	0.000	0.000	0.000	0.000	0.000
103 AGING TIME (DAYS)	6.000	11.000	5.000	26.000	21.000
104 TEMPERATURE (DEG. F)	70.000	69.000	73.000	73.000	73.000
105 PH	6.100	5.000	4.900	5.100	4.900
106 VISCOSITY 1/60 (CPS)	67.500	150.000	170.000	100.000	100.000
107 VISCOSITY 1/30 (CPS)	77.000	235.000	240.000	171.000	100.000
108 VISCOSITY 1/12 (CPS)	97.500	365.000	387.500	275.000	375.000
109 THIXOTROPIC INDEX	1.440	2.430	2.280	2.700	3.700

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS F SINTERING

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
PARAMETER NUMBER AND NAME										
110 SINTERING TIME (HOURS)	4.000	4.000	4.000	12.000	12.000	4.000	4.000	4.000	4.000	12.000
111 TEMPERATURE (DEG. C)	1100.000	1100.000	1100.000	1040.000	1040.000	1100.000	1100.000	1100.000	1100.000	1040.000
112 VACUUM (MICRO)	125.000	1.000	1.000	1.000	1.000	125.000	125.000	1.000	1.000	1.000
113 TIME .GT. 200 DEG C HRS	30.250	26.750	26.750	20.000	20.000	30.250	30.250	26.750	26.750	20.000
114 TIME .GT. 400 DEG C HRS	23.000	21.500	21.500	18.750	18.750	23.000	23.000	21.500	21.500	18.750
115 TIME .GT. 600 DEG C HRS	16.000	16.250	16.250	17.250	17.250	16.000	16.000	16.250	16.250	17.250
116 TIME .GT. 800 DEG C HRS	9.000	10.750	10.750	14.500	14.500	9.000	9.000	10.750	10.750	14.500
117 TIME .GT. 900 DEG C HRS	7.250	8.250	8.250	12.750	12.750	7.250	7.250	8.250	8.250	12.750
118 TIME .GT. 1000 DEG C HRS	5.500	6.000	6.000	12.000	12.000	5.500	5.500	6.000	6.000	12.000
119 DEG HRS .GT. 200 DEG C	13675.452	13463.306	13463.306	13798.096	13798.096	13675.452	13675.452	13463.306	13463.306	13798.096
120 DEG HRS .GT. 400 DEG C	8340.548	8618.181	8618.181	9914.985	9914.985	8340.548	8340.548	8618.181	8618.181	9914.985
121 DEG HRS .GT. 600 DEG C	4424.058	4847.056	4847.056	6296.435	6296.435	4424.058	4424.058	4847.056	4847.056	6296.435
122 DEG HRS .GT. 800 DEG C	1923.708	2150.473	2150.473	3091.301	3091.301	1923.708	1923.708	2150.473	2150.473	3091.301
123 DEG HRS .GT. 900 DEG C	1113.209	1207.515	1207.515	1725.368	1725.368	1113.209	1113.209	1207.515	1207.515	1725.368
124 DEG HRS .GT. 1000 DEG C	470.835	514.490	514.490	480.000	480.000	470.835	470.835	514.490	514.490	480.000
125 TIME 21-900 DEG C (HRS)	25.750	20.000	20.000	4.250	4.250	25.750	25.750	20.000	20.000	4.250
126 TIME 900-21 DEG C (HRS)	3.750	3.500	3.500	4.500	4.500	3.750	3.750	3.500	3.500	4.500
127 OXYGEN ANALYSIS (PRCNT)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
128 OXYGEN ANALYSIS +/- PRCNT	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
129 PERMEABILITY	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
130 GREEN DENSITY (GM/CM3)	1.720	1.720	1.720	1.710	1.710	1.730	1.730	1.740	1.740	1.730
131 PERCENT WEIGHT LOSS	0.000*	.560	.560	.950	.950	0.000*	0.000*	.540	.540	.960

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JC0542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS F SINTERING

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABCFG	ABCFG	ABDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
110 SINTERING TIME (HOURS)	12.000	4.000	4.000	4.000	12.000	4.000	4.000	4.000	4.000	12.000
111 TEMPERATURE (DEG. C)	1040.000	1100.000	1100.000	1100.000	1040.000	1100.000	1100.000	1100.000	1100.000	1040.000
112 VACUUM (MICRO)	1.000	1.000	125.000	1.000	1.000	125.000	1.000	125.000	125.000	1.000
113 TIME .GT. 200 DEG C HRS	20.000	26.750	30.250	26.750	20.000	30.250	26.750	30.250	30.250	20.000
114 TIME .GT. 400 DEG C HRS	18.750	21.500	23.000	21.500	18.750	23.000	21.500	23.000	23.000	18.750
115 TIME .GT. 600 DEG C HRS	17.250	16.250	16.000	16.250	17.250	16.000	16.250	16.000	16.000	17.250
116 TIME .GT. 800 DEG C HRS	14.500	10.750	9.000	10.750	14.500	9.000	10.750	9.000	9.000	14.500
117 TIME .GT. 900 DEG C HRS	12.750	8.250	7.250	8.250	12.750	7.250	8.250	7.250	7.250	12.750
118 TIME .GT. 1000 DEG C HRS	12.000	6.000	5.500	6.000	12.000	5.500	6.000	5.500	5.500	12.000
119 DEG HRS .GT. 200 DEG C	13798.096	13463.306	13675.452	13463.306	13798.096	13675.452	13463.306	13675.452	13675.452	13798.096
120 DEG HRS .GT. 400 DEG C	9914.985	8618.181	8340.548	8618.181	9914.985	8340.548	8618.181	8340.548	8340.548	9914.985
121 DEG HRS .GT. 600 DEG C	6296.435	4847.056	4424.058	4847.056	6296.435	4424.058	4847.056	4424.058	4424.058	6296.435
122 DEG HRS .GT. 800 DEG C	3091.301	2150.473	1923.708	2150.473	3091.301	1923.708	2150.473	1923.708	1923.708	3091.301
123 DEG HRS .GT. 900 DEG C	1725.368	1207.515	1113.209	1207.515	1725.368	1113.209	1207.515	1113.209	1113.209	1725.368
124 DEG HRS .GT. 1000 DEG C	480.000	514.490	470.835	514.490	480.000	470.835	514.490	470.835	470.835	480.000
125 TIME 21-900 DEG C (HRS)	4.250	20.000	25.750	20.000	4.250	25.750	20.000	25.750	25.750	4.250
126 TIME 900-21 DEG C (HRS)	4.500	3.500	3.750	3.500	4.500	3.750	3.500	3.750	3.750	4.500
127 OXYGEN ANALYSIS (PRCNT)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
128 OXYGEN ANALYSIS +/- PRCNT	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
129 PERMEABILITY	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
130 GREEN DENSITY (GM/CM3)	1.730	1.670	1.620	1.640	1.620	1.750	1.780	1.680	1.680	1.730
131 PERCENT WEIGHT LOSS	.960	.580	1.350	0.000*	0.000*	1.260	0.000*	1.400	1.400	.960

ADAPTRONICS,INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS F SINTERING

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
PARAMETER NUMBER AND NAME										
110 SINTERING TIME (HOURS)	4.000	4.000	4.000	12.000	4.000	4.000	4.000	4.000	12.000	4.000
111 TEMPERATURE (DEG. C)	1100.000	1100.000	1100.000	1040.000	1100.000	1100.000	1100.000	1100.000	1040.000	1100.000
112 VACUUM (MICRO)	125.000	125.000	1.000	1.000	125.000	75.000	125.000	125.000	1.000	0.000
113 TIME .GT. 200 DEG C HRS	30.250	30.250	26.750	20.000	30.250	15.500	30.250	30.250	20.000	15.500
114 TIME .GT. 400 DEG C HRS	23.000	23.000	21.500	18.750	23.000	12.750	23.000	23.000	18.750	12.750
115 TIME .GT. 600 DEG C HRS	16.000	16.000	16.250	17.250	16.000	10.250	16.000	16.000	17.250	10.250
116 TIME .GT. 800 DEG C HRS	9.000	9.000	10.750	14.500	9.000	8.000	9.000	9.000	14.500	8.000
117 TIME .GT. 900 DEG C HRS	7.250	7.250	8.250	12.750	7.250	6.500	7.250	7.250	12.750	6.500
118 TIME .GT. 1000 DEG C HRS	5.500	5.500	6.000	12.000	5.500	5.250	5.500	5.500	12.000	5.250
119 DEG HRS .GT. 200 DEG C	13675.452	13675.452	13463.306	13798.096	13675.452	8719.446	13675.452	13675.452	13798.096	8719.446
120 DEG HRS .GT. 400 DEG C	8340.548	8340.548	8618.181	9914.985	8340.548	5894.507	8340.548	8340.548	9914.985	5894.507
121 DEG HRS .GT. 600 DEG C	4424.058	4424.058	4847.056	6296.435	4424.058	3576.442	4424.058	4424.058	6296.435	3576.442
122 DEG HRS .GT. 800 DEG C	1923.708	1923.708	2150.473	3091.301	1923.708	1764.191	1923.708	1923.708	3091.301	1764.191
123 DEG HRS .GT. 900 DEG C	1113.209	1113.209	1207.515	1725.368	1113.209	1049.565	1113.209	1113.209	1725.368	1049.565
124 DEG HRS .GT. 1000 DEG C	470.835	470.835	514.490	480.000	470.835	461.689	470.835	470.835	480.000	461.689
125 TIME 21-900 DEG C (HRS)	25.750	25.750	20.000	4.250	25.750	7.250	25.750	25.750	4.250	7.250
126 TIME 900-21 DEG C (HRS)	3.750	3.750	3.500	4.500	3.750	4.000	3.750	3.750	4.500	4.000
127 OXYGEN ANALYSIS (PRCNT)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
128 OXYGEN ANALYSIS +/- PRCNT	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
129 PERMEABILITY	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
130 GREEN DENSITY (GM/CM3)	1.660	1.730	1.710	1.710	1.630	1.540	1.730	1.630	1.660	1.720
131 PERCENT WEIGHT LOSS	.640	.600	.200	.290	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

SUBPROCESS F SINTERING

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
PARAMETER NUMBER AND NAME					
110 SINTERING TIME (HOURS)	4.000	4.000	4.000	4.000	4.000
111 TEMPERATURE (DEG. C)	1100.000	1100.000	1100.000	1100.000	1100.000
112 VACUUM (MICRO)	0.000	0.000	0.000	70.000	70.000
113 TIME .GT. 200 DEG C HRS	15.500	26.750	26.750	20.000	20.000
114 TIME .GT. 400 DEG C HRS	12.750	21.500	21.500	18.750	18.750
115 TIME .GT. 600 DEG C HRS	10.250	16.250	16.250	17.250	17.250
116 TIME .GT. 800 DEG C HRS	8.000	10.750	10.750	14.500	14.500
117 TIME .GT. 900 DEG C HRS	6.500	8.250	8.250	12.750	12.750
118 TIME .GT. 1000 DEG C HRS	5.250	6.000	6.000	12.000	12.000
119 DEG HRS .GT. 200 DEG C	8719.446	13463.306	13463.306	13798.096	13798.096
120 DEG HRS .GT. 400 DEG C	5894.507	8618.181	8618.181	9914.985	9914.985
121 DEG HRS .GT. 600 DEG C	3576.442	4847.056	4847.056	6296.435	6296.435
122 DEG HRS .GT. 800 DEG C	1764.191	2150.473	2150.473	3091.301	3091.301
123 DEG HRS .GT. 900 DEG C	1049.565	1207.515	1207.515	1725.368	1725.368
124 DEG HRS .GT. 1000 DEG C	461.689	514.490	514.490	480.000	480.000
125 TIME 21-900 DEG C (HRS)	7.250	20.000	20.000	4.250	4.250
126 TIME 900-21 DEG C (HRS)	4.000	3.500	3.500	4.500	4.500
127 OXYGEN ANALYSIS (PRCNT)	0.000*	0.000*	0.000*	1.570	1.690
128 OXYGEN ANALYSIS +/- PRCNT	0.000*	0.000*	0.000*	.390	.400
129 PERMEABILITY	0.000*	0.000*	0.000*	0.000*	0.000*
130 GREEN DENSITY (GM/CM3)	1.730	1.720	1.760	1.740	1.720
131 PERCENT WEIGHT LOSS	0.000*	0.000*	0.000*	1.000	1.900

SUBPROCESS G NITRIDING

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
132 FURNACE LOAD (GMS)	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000
133 VACUUM LEVEL (MICRO)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
134 LEAK-UP RATE	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
135 HOURS PRIOR N2 FLOW	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
136 ATMOSPHERE PRCNT N2	.960	.960	.960	.960	.960	.960	.960	.960	.960	.960
137 ATMOSPHERE PRCNT H2	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
138 NITRID. TIME (DAYS)	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000
139 PEAK TEMP (DEG. C)	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000
140 SHIELDING 0=NO,1=YES	0.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
141 TIME .GT 400 DEG C DAYS	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208
142 TIME .GT 600 DEG C DAYS	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135
143 TIME .GT 800 DEG C DAYS	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031
144 TIME .GT 1000 DEG C DAYS	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708
145 TIME .GT 1100 DEG C DAYS	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031
146 TIME .GT 1200 DEG C DAYS	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010
147 TIME .GT 1300 DEG C DAYS	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
148 DEG DAYS .GT. 400 DEG C	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351
149 DEG DAYS .GT. 600 DEG C	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137
150 DEG DAYS .GT. 800 DEG C	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643
151 DEG DAYS .GT. 1000 DEG C	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001
152 DEG DAYS .GT. 1100 DEG C	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014
153 DEG DAYS .GT. 1200 DEG C	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243
154 DEG DAYS .GT. 1300 DEG C	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582
155 WEIGHT GAIN PRCNT	55.890	54.400	56.800	54.700	56.600	56.200	57.300	56.100	56.500	55.600
156 NITRIDED DENSITY (GM/CM3)	2.730	2.660	2.690	2.670	2.680	2.730	2.760	2.710	2.740	2.720

ADAPTRONICS,INC. SLIP CASTING ADAPTIVE CONTROL JCE542

DATA BASE SUPPLIED BY AIRESEARCH CASTING COMPANY TORRANCE , CALIFORNIA

FEBRUARY 1979 REVISED 12/04/79

SUBPROCESS G NITRIDING

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
132 FURNACE LOAD (GMS)	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000
133 VACUUM LEVEL (MICRO)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
134 LEAK-UP RATE	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
135 HOURS PRIOR N2 FLOW	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
136 ATMOSPHERE PRCNT N2	.960	.960	.960	.960	.960	.960	.960	.960	.960	.960
137 ATMOSPHERE PRCNT H2	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
138 NITRID. TIME (DAYS)	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000
139 PEAK TEMP (DEG. C)	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000
140 SHIELDING 0=NO,1=YES	1.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000
141 TIME .GT 400 DEG C DAYS	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208
142 TIME .GT 600 DEG C DAYS	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135
143 TIME .GT 800 DEG C DAYS	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031
144 TIME .GT 1000 DEG C DAYS	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708
145 TIME .GT 1100 DEG C DAYS	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031
146 TIME .GT 1200 DEG C DAYS	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010
147 TIME .GT 1300 DEG C DAYS	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
148 DEG DAYS .GT. 400 DEG C	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351
149 DEG DAYS .GT. 600 DEG C	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137
150 DEG DAYS .GT. 800 DEG C	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643
151 DEG DAYS .GT. 1000 DEG C	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001
152 DEG DAYS .GT. 1100 DEG C	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014
153 DEG DAYS .GT. 1200 DEG C	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243
154 DEG DAYS .GT. 1300 DEG C	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582
155 WEIGHT GAIN PRCNT	56.700	57.900	59.300	58.000	61.200	58.900	58.400	58.700	58.600	57.600
156 NITRIDED DENSITY (GM/CM3)	2.730	2.620	2.570	2.590	2.490	2.790	2.820	2.660	2.690	2.630

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS G NITRIDING

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
132 FURNACE LOAD (GMS)	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	3350.000	2988.000
133 VACUUM LEVEL (MICRO)	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	10.000
134 LEAK-UP RATE	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	8.000
135 HOURS PRIOR N2 FLOW	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	2.500
136 ATMOSPHERE PRCNT N2	.960	.960	.960	.960	.960	.960	.960	.960	.960	.960
137 ATMOSPHERE PRCNT H2	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
138 NITRID. TIME (DAYS)	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	11.000
139 PEAK TEMP (DEG. C)	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1400.000	1371.000
140 SHIELDING 0=NO,1=YES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
141 TIME .GT 400 DEG C DAYS	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	21.208	11.198
142 TIME .GT 600 DEG C DAYS	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	21.135	11.094
143 TIME .GT 800 DEG C DAYS	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	21.031	11.000
144 TIME .GT 1000 DEG C DAYS	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	20.708	10.406
145 TIME .GT 1100 DEG C DAYS	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	9.031	7.677
146 TIME .GT 1200 DEG C DAYS	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	6.010	4.906
147 TIME .GT 1300 DEG C DAYS	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	1.677
148 DEG DAYS .GT. 400 DEG C	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	15322.351	8560.276
149 DEG DAYS .GT. 600 DEG C	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	11088.137	6331.841
150 DEG DAYS .GT. 800 DEG C	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	6871.643	4122.475
151 DEG DAYS .GT. 1000 DEG C	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	2692.001	1937.839
152 DEG DAYS .GT. 1100 DEG C	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1352.014	1033.393
153 DEG DAYS .GT. 1200 DEG C	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	600.243	403.426
154 DEG DAYS .GT. 1300 DEG C	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	149.582	62.401
155 WEIGHT GAIN PRCNT	60.200	59.400	59.700	59.000	58.900	58.000	58.200	53.500	54.700	57.900
156 NITRIDED DENSITY (GM/CM3)	2.680	2.760	2.720	2.730	2.730	2.550	2.720	2.540	2.500	2.730

ADAPTRONICS,INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

SUBPROCESS 6 NITRIDING

PARAMETER NUMBER AND NAME					
SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
132 FURNACE LOAD (GMS)	2989.000	2988.000	2988.000	4460.000	4460.000
133 VACUUM LEVEL (MICRO)	10.000	10.000	10.000	200.000	200.000
134 LEAK-UP RATE	8.000	8.000	8.000	10.000	10.000
135 HOURS PRIOR N2 FLOW	2.500	2.500	2.500	2.000	2.000
136 ATMOSPHERE PRCNT N2	.960	.960	.960	.960	.960
137 ATMOSPHERE PRCNT H2	.040	.040	.040	.040	.040
138 NITRID. TIME (DAYS)	11.000	11.000	11.000	12.000	12.000
139 PEAK TEMP (DEG. C)	1371.000	1371.000	1371.000	1410.000	1410.000
140 SHIELDING 0=NO,1=YES	1.000	1.000	1.000	1.000	1.000
141 TIME .GT 400 DEG C DAYS	11.198	11.198	11.198	11.542	11.542
142 TIME .GT 600 DEG C DAYS	11.094	11.094	11.094	11.479	11.479
143 TIME .GT 800 DEG C DAYS	11.000	11.000	11.000	11.417	11.417
144 TIME .GT 1000 DEG C DAYS	10.406	10.406	10.406	11.344	11.344
145 TIME .GT 1100 DEG C DAYS	7.677	7.677	7.677	9.354	9.354
146 TIME .GT 1200 DEG C DAYS	4.906	4.906	4.906	6.927	6.927
147 TIME .GT 1300 DEG C DAYS	1.677	1.677	1.677	3.833	3.833
148 DEG DAYS .GT. 400 DEG C	8560.276	8560.276	8560.276	9494.792	9494.792
149 DEG DAYS .GT. 600 DEG C	6331.841	6331.841	6331.841	7192.374	7192.374
150 DEG DAYS .GT. 800 DEG C	4122.475	4122.475	4122.475	4903.506	4903.506
151 DEG DAYS .GT. 1000 DEG C	1937.839	1937.839	1937.839	2627.881	2627.881
152 DEG DAYS .GT. 1100 DEG C	1033.393	1033.393	1033.393	1575.548	1575.548
153 DEG DAYS .GT. 1200 DEG C	403.426	403.426	403.426	761.392	761.392
154 DEG DAYS .GT. 1300 DEG C	62.401	62.401	62.401	211.190	211.190
155 WEIGHT GAIN PRCNT	59.200	59.900	56.600	59.100	59.100
156 NITRIDED DENSITY (GM/CM3)	2.750	2.740	2.750	2.790	2.760

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JOB542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

FINAL ANALYSIS

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
157 ALPHA (X-RAY REL. PRCNT)	82.900	85.700	84.000	79.500	85.500	85.100	89.000	84.900	85.100	87.200
158 BETA (X-RAY REL. PRCNT)	11.600	11.500	12.500	18.300	12.000	12.200	9.200	11.900	11.500	9.900
159 SI2ON2 (X-RAY REL. PRCNT)	5.500	2.700	3.500	2.200	2.500	2.700	1.800	3.200	3.400	2.900
160 SI (X-RAY REL. PRCNT)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
161 RATIO ALPHA/BETA	7.147	7.452	6.720	4.344	7.125	6.975	9.674	7.134	7.400	8.808
162 RATIO BETA/ALPHA	.140	.134	.149	.230	.140	.143	.103	.140	.135	.114
163 RATIO SI2ON2/ALPHA	.066	.032	.042	.028	.029	.032	.020	.038	.040	.033
164 RATIO SI2ON2/BETA	.474	.235	.280	.120	.208	.221	.196	.269	.296	.293
165 PORE SIZE DIST.	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCE542

DATA BASE SUPPLIED BY
AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

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FINAL ANALYSIS

SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
157 ALPHA (X-RAY REL. PRCNT)	85.200	82.700	78.000	84.400	75.200	89.200	83.600	87.900	89.300	86.200
158 BETA (X-RAY REL. PRCNT)	12.000	13.100	19.700	12.900	24.800	8.600	12.300	7.800	8.400	8.600
159 SI2ON2 (X-RAY REL. PRCNT)	2.800	4.200	2.300	2.700	0.000	2.100	4.000	4.300	2.300	5.200
160 SI (X-RAY REL. PRCNT)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
161 RATIO ALPHA/BETA	7.100	6.313	3.959	6.543	3.032	10.372	6.797	11.269	10.631	10.023
162 RATIO BETA/ALPHA	.141	.158	.253	.153	.330	.096	.147	.089	.094	.100
163 RATIO SI2ON2/ALPHA	.033	.051	.029	.032	0.000	.024	.048	.049	.026	.060
164 RATIO SI2ON2/BETA	.233	.321	.117	.209	0.000	.244	.325	.551	.274	.605
165 PORE SIZE DIST.	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCB542

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TORRANCE , CALIFORNIA

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FINAL ANALYSIS

SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
PARAMETER NUMBER AND NAME										
157 ALPHA (X-RAY REL. PRCNT)	84.000	75.400	76.800	78.000	75.700	87.100	79.600	78.000	78.300	70.300
158 BETA (X-RAY REL. PRCNT)	13.200	22.100	21.100	18.700	23.000	10.800	18.000	19.000	18.200	26.100
159 SI2ON2 (X-RAY REL. PRCNT)	2.800	2.500	2.100	3.300	1.300	2.100	2.400	2.900	3.400	3.600
160 SI (X-RAY REL. PRCNT)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
161 RATIO ALPHA/BETA	6.364	3.412	3.640	4.171	3.291	8.065	4.422	4.105	4.302	2.693
162 RATIO BETA/ALPHA	.157	.293	.275	.240	.304	.124	.226	.244	.232	.371
163 RATIO SI2ON2/ALPHA	.033	.033	.027	.042	.017	.024	.030	.037	.043	.051
164 RATIO SI2ON2/BETA	.212	.113	.100	.176	.057	.194	.133	.153	.187	.138
165 PORE SIZE DIST.	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JC0542

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FEBRUARY 1979
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FINAL ANALYSIS

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
PARAMETER NUMBER AND NAME					
157 ALPHA (X-RAY REL. PRCNT)	68.400	69.800	73.700	72.200	71.900
158 BETA (X-RAY REL. PRCNT)	28.100	29.200	20.900	22.700	22.900
159 SI2ON2 (X-RAY REL. PRCNT)	3.000	0.000	2.000	0.000	0.000
160 SI (X-RAY REL. PRCNT)	.500	1.000	3.300	1.300	1.600
161 RATIO ALPHA/BETA	2.434	2.390	3.526	3.181	3.140
162 RATIO BETA/ALPHA	.411	.418	.284	.314	.318
163 RATIO SI2ON2/ALPHA	.044	0.000	.027	0.000	0.000
164 RATIO SI2ON2/BETA	.107	0.000	.096	0.000	0.000
165 PORE SIZE DIST.	0.000*	0.000*	0.000*	0.000*	0.000*

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCR542

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AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

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STRENGTH DATA

SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABCFG	ABCFG	ABDFG
PROCESS CODE NUMBER	11111	11121	11122	11131	11132	11211	11212	11221	11222	11231
OBSERVATION NUMBER	1	2	3	4	5	6	7	8	9	10
PARAMETER NUMBER AND NAME										
166 MOR MAXIMUM VALUE (KSI)	27.100	25.900	29.400	26.600	31.400	32.300	38.000	34.900	38.400	32.800
167 MOR MINIMUM VALUE (KSI)	14.400	13.200	12.700	9.700	12.290	19.900	25.600	21.600	27.600	22.800
168 MOR MEAN VALUE (KSI)	23.140	21.330	25.590	18.690	24.070	27.110	31.920	25.470	33.260	28.020
169 MOR STAND. DEVIATION	3.800	4.370	5.720	5.810	5.310	3.480	3.490	4.230	3.260	2.970
170 WEIBULL CHARACTERISTIC	24.707	23.068	27.831	20.749	26.158	28.579	33.415	27.211	34.666	29.294
171 WEIBULL SLOPE (SHAPE)	7.175	5.646	5.135	3.572	5.208	9.326	11.048	7.087	12.417	11.425
172 CORRELATION COEF.	.956	.975	.908	.978	.969	.980	.986	.818	.978	.979
173 PROCESS CODE	11111.000	11121.000	11122.000	11131.000	11132.000	11211.000	11212.000	11221.000	11222.000	11231.000

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCP542

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AIRESEARCH CASTING COMPANY
TORRANCE , CALIFORNIA

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REVISED 12/04/79

STRENGTH DATA

SUBPROCESS DESIGNATION	ABCFG	ABDFG	ABCFG	ABDFG	ABCFG	ABDFG	ABDFG	ABDFG	ABCFG	AEDFG
PROCESS CODE NUMBER	11232	12121	12212	12221	12231	13111	13121	14111	14112	14132
OBSERVATION NUMBER	11	12	13	14	15	16	17	18	19	20
PARAMETER NUMBER AND NAME										
166 MOR MAXIMUM VALUE (KSI)	39.100	35.900	37.100	34.300	38.300	31.200	40.300	29.700	34.080	31.500
167 MOR MINIMUM VALUE (KSI)	23.290	16.709	25.100	20.700	30.500	18.100	19.600	19.600	23.600	15.300
168 MOR MEAN VALUE (KSI)	32.960	28.939	31.620	26.840	34.310	24.570	28.030	25.920	29.380	26.910
169 MOR STAND. DEVIATION	3.620	6.750	3.620	3.960	2.840	4.650	6.330	3.300	2.970	6.530
170 WEIBULL CHARACTERISTIC	34.514	31.540	33.166	28.493	35.542	26.452	30.499	27.313	30.655	29.411
171 WEIBULL SLOPE (SHAPE)	10.999	4.901	10.539	8.049	14.846	6.153	5.080	9.435	12.025	4.696
172 CORRELATION COEF.	.963	.948	.957	.965	.975	.947	.956	.977	.991	.928
173 PROCESS CODE	11232.000	12121.000	12212.000	12221.000	12231.000	13111.000	13121.000	14111.000	14112.000	14132.000

ADAPTRONICS,INC.
SLIP CASTING ADAPTIVE CONTROL
JCH542

DATA BASE SUPPLIED BY
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TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

STRENGTH DATA

PARAMETER NUMBER AND NAME										
SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	21111	26111	26121	26131	26211	27111	31111	35111	35131	26112
OBSERVATION NUMBER	21	22	23	24	25	26	27	28	29	30
166 MOR MAXIMUM VALUE (KSI)	37.200	50.700	47.800	48.100	49.400	32.600	42.600	32.500	30.660	47.500
167 MOR MINIMUM VALUE (KSI)	26.300	21.200	22.700	30.500	35.130	16.400	23.000	21.000	24.700	36.300
168 MOR MEAN VALUE (KSI)	33.190	43.470	41.820	41.380	45.020	27.700	36.090	27.130	27.970	43.800
169 MOR STAND. DEVIATION	3.370	10.130	8.720	4.700	4.570	5.350	5.470	4.180	3.230	4.410
170 WEIBULL CHARACTERISTIC	34.551	47.396	45.281	43.382	46.980	29.848	38.365	28.864	29.344	45.700
171 WEIBULL SLOPE (SHAPE)	11.914	4.903	5.536	10.625	11.969	6.019	7.815	7.681	10.432	12.100
172 CORRELATION COEF.	.987	.950	.919	.986	.975	.906	.968	.989	.989	.940
173 PROCESS CODE	21111.000	26111.000	26121.000	26131.000	26211.000	27111.000	31111.000	35111.000	35131.000	26112.000

ADAPTRONICS, INC.
SLIP CASTING ADAPTIVE CONTROL
JCP542

DATA BASE SUPPLIED BY
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TORRANCE , CALIFORNIA

FEBRUARY 1979
REVISED 12/04/79

STRENGTH DATA

SUBPROCESS DESIGNATION	ABDFG	ABDFG	ABDFG	ABDFG	ABDFG
PROCESS CODE NUMBER	39312	46212	49212	46112	49212
OBSERVATION NUMBER	31	32	33	34	35
PARAMETER NUMBER AND NAME					
166 MOR MAXIMUM VALUE (KSI)	45.700	50.200	56.000	54.700	48.500
167 MOR MINIMUM VALUE (KSI)	26.000	40.500	15.900	39.300	39.800
168 MOR MEAN VALUE (KSI)	40.500	46.500	36.600	47.800	44.300
169 MOR STAND. DEVIATION	5.770	3.610	13.660	5.540	3.120
170 WEIBULL CHARACTERISTIC	42.900	48.000	41.000	50.200	45.700
171 WEIBULL SLOPE (SHAPE)	8.300	15.800	2.910	10.400	17.550
172 CORRELATION COEF.	.951	.953	.979	.989	.992
173 PROCESS CODE	39312.000	46212.000	49212.000	46112.000	49212.000